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Original Communications

STREPTOMYCIN AS AN ADJUNCT IN SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS

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IT IS a pleasure to open this meeting with a discussion of the merits of streptomycin, the first and only specific therapeutic agent which has come to the assistance of the surgeon and phthisiologist since the institution of collapse therapy for pulmonary tuberculosis.

At the end of the twenty-five-year period ending in 1945, thoracoplasty, the major surgical collapse procedure, had probably reached the zenith of its possibilities as a therapeutic measure in terms of maximum percentage of cavity closure and sputum conversion with minimum mortality and morbidity. Contributing to this was a tremendous experience with the behavior of tuberculosis under surgical management, increased surgical skill, and progressive improvements in the ancillary factors of anesthesia, blood-loss replacement, improved pre- and postoperative care, smaller stage operations, etc. By far the greatest factor, however, in reducing mortality and morbidity in the operated group has been experience and skill in the selection of cases for operation, and the proper timing of operative interference. This has led to the general recognition of the so-called "good chronic" as the standard risk for thoracoplasty. It is in this group of patients that most clinics have been able to achieve a low operative mortality of 2 to 3 per cent, a low incidence of acute postoperative spread and exacerbation, and a rate of cavity closure and sputum conversion approximating 70 per cent. The factors which increase the operative risk, such as age, extent and activity of disease, bilateral involvement, toxic constitutional symptoms, extrapulmonary tuberculosis, cardiac impairment, large sputum output, marked reduction of the respiratory functional capacity, diabetes, etc., were also generally recognized. The combination of one or more of these factors relegated a large group of patients with cavitary disease to the status of substandard surgical risks. In

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From the Surgical Service of the Triboro Hospital.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

many of these patients the preoperative bed rest waiting period was often prolonged, and a great many never did reach the status of a fair operative risk, and thus were denied the benefits of surgical collapse.

The mortality and morbidity statistics could be improved or worsened in accordance with the manner in which operative indications were limited to the standard risk group, or the boldness with which they were extended into the substandard risk group.

After 1942 following the stimulating work of Churchill and Klopstock, and its further extension by Overholt and Maier, resection surgery for tuberculosis began to take a place in the surgical armamentarium. The work of these early pioneers in the field was plagued not so much by operative mortality per se, as by a high incidence of fresh postoperative spread or exacerbation of old quiescent lesions attributed to dissemination of tubercle laden bronchial secretions during operation. This factor was improved to some extent by the Overholt face-down position during operation, but early and late exacerbation and spread continued to hinder the wider application of resection surgery to the problems of cavitary tuberculosis.

Such was the status of the surgical treatment of pulmonary tuberculosis, when in 1945 and 1946 the work of Hinshaw and others in the treatment of tuberculosis with streptomycin began to appear.

To summarize briefly: After one year to eighteen months clinical trial, the following were some of the facts about streptomycin that became apparent.

1. At long last there was a therapeutic agent tolerated by human beings which had a specific antibacterial effect on the tubercle bacillus.

2. While streptomycin had no rapidly effective curative action on chronic productive or cavitary tuberculosis, soft pulmonary lesions of recent origin tended to improve promptly.

3. Dosages of 2 Gm. or more per day over a prolonged period produced toxic manifestations characterized by impaired function of the eighth cranial nerve in a large proportion of treated patients. These toxic manifestations were decreased or eliminated by reduction of the dosage to 1 Gm. per day, and an effective in vivo concentration of the drug could still be maintained with this dosage.

4. Tubercle bacilli became resistant to streptomycin in varying periods, generally from 90 to 120 days, thus placing a time limit on the beneficial effects of the drug.

5. Laryngeal and tracheobronchial tuberculosis were benefited by parenteral streptomyin treatment with resultant improvement in nutrition, decrease in toxicity, and general improvement in the patients' condition.

Scrutiny of these facts led to the conclusion that streptomycin with its acknowledged beneficial effect on progressive lesions of recent origin, and its limited period of effectiveness, might be more useful as an adjunct in the surgical treatment of pulmonary tuberculosis than in any other mode of use. We hoped that it might improve our results from resection surgery and widen our indications by being prophylactic for the early and late postoperative dissemination and exacerbation of quiescent lesions. We anticipated that it might improve the risk status of some of those in the substandard risk group for thoracoplasty, and shorten the time of their preoperative cooling off period, thus broadening the field of major surgical collapse therapy without undue increase in the morbidity and mortality.

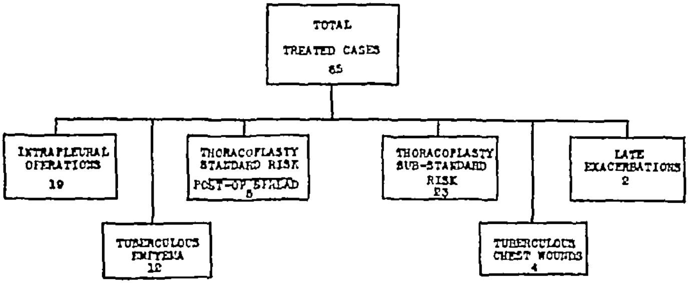


Fig. 1.—Streptomycin-treated cases, January, 1947, to January, 1948, Surgical Service, Triboro Hospital, New York, N. Y.

We had occasion during 1946 to observe the effects of the drug sporadically in a very few cases. Streptomycin in quantities sufficient for a fair clinical trial was furnished to us at Triboro Hospital, as soon as possible within budgetary limitations by Dr. Edward M. Bernecker, Commissioner of Hospitals of New York, N. Y. This was in the early spring of 1947. All of the streptomycin used in this series of cases was provided free of charge to the patients by the Department of Hospitals, City of New York.

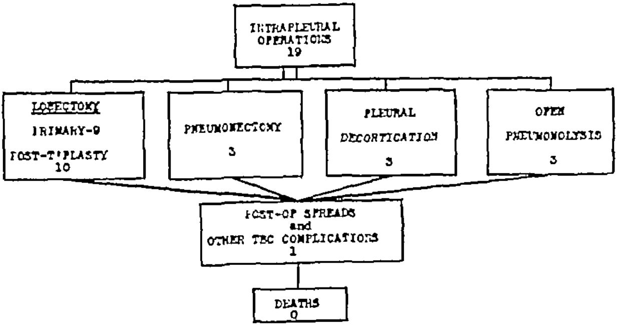


Fig. 2.

We are presenting a summary of our experience with the drug on the surgical service of Triboro Hospital during 1947, the first year of its use.

There was a total of 85 cases, 65 of the patients treated with streptomycin, and 20 thoracoplasties not treated with streptomycin. We have divided them into six groups as illustrated in Fig. 1. There were 19 intrapleural procedures including the resection cases; 23 substandard risk thoracoplasty cases; 5

cases of postoperative spread or exacerbation in a series of 25 standard risk thoracoplasty cases with no preoperative streptomycin treatment; 12 cases of tuberculous empyema; 4 tuberculous chest wounds, and 2 late exacerbations following surgery done in previous years.

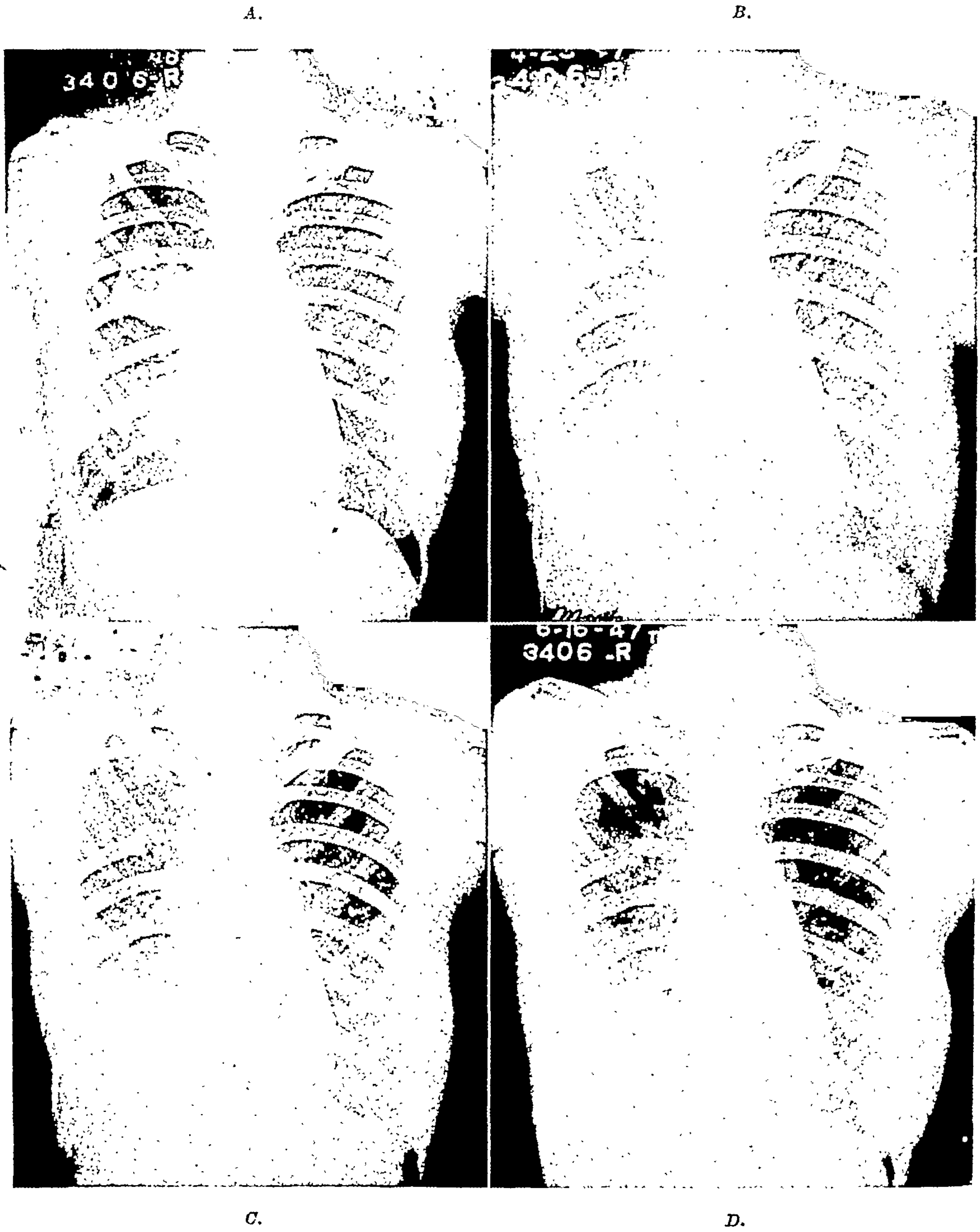
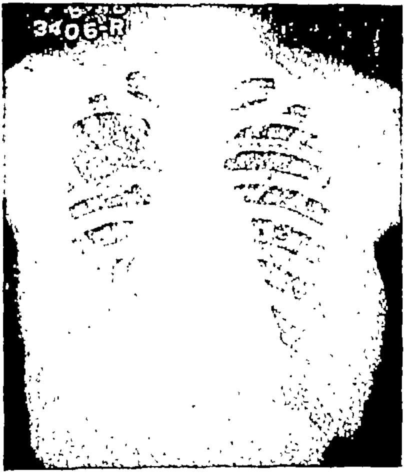


Fig. 3, *A* to *D* (Case 1).—*A*, Dec. 17, 1946, preoperative. *B*, April 23, 1947, one month postoperative, lobectomy right upper lobe and right middle lobe. *C*, May 19, 1947, two months postoperative. Note exudative lesion in expanded residual lower lobe. *D*, June 16, 1947, lesion receding after one month of streptomycin therapy.

All patients soon after the institution of streptomycin therapy showed a marked subsidence of cough, diminution in the daily sputum output, and diminution in the bacillary content of the sputum. This was particularly dramatic in patients with copious outputs of 8 to 10 ounces of sputum per day, and was usually accompanied by rapid improvement in the patient's general condition, decrease in toxicity, improved feeling of well-being, and improvement in the nutrition. These changes often took place within ten days to two weeks after the initiation of therapy; in some cases the progress was slower. Most patients on preoperative streptomycin therapy came to operation practically dry as far as sputum output was concerned, and we feel that this is one of the most important contributions of the drug to the prevention of postoperative pulmonary complications.



E.

Fig. 3, E.—March 5, 1948, one year postoperative.

The operations in this series were performed by a number of different surgeons. The majority of the operative procedures were performed by the resident staff with the supervision and assistance of the attending staff.

We have grouped all the intrapleural procedures together (Fig. 2) comprising 10 lobectomies, 3 total pneumonectomies, 3 pleural decortications, and 3 intrapleural pneumonolyses done in bilateral cases.

Streptomycin was used as follows in the decortication and open pneumonolysis cases: 1 Gm. per day was given for seven days preoperatively and fourteen days postoperatively. The postoperative course in all 6 cases was benign, and there were no tuberculous or other serious complications.

In all the resection cases, streptomycin was given intramuscularly in dosages of 0.5 Gm. every twelve hours for three to four weeks preoperatively and for ninety days postoperatively, with the exception of one patient who received streptomycin fourteen days preoperatively and fourteen days postoperatively.

CASE REPORTS

CASE 1.—A 26-year-old white woman was admitted to Triboro Hospital in May, 1946, with a productive and cavernous lesion in the right upper and middles lobes (Fig. 3, *A*). On March 22, 1947, after fourteen days of preliminary streptomycin therapy, a lobectomy of the right upper and middle lobes was done. The postoperative course was benign and uneventful and streptomycin was discontinued fourteen days postoperatively (Fig. 3, *B*). On May 15, 1947, a symptomless early infiltration in the apex of the right lower lobe was noted on checkup x-ray examination (Fig. 3, *C*). Streptomycin therapy was reinstituted and continued for 120 days. The infiltration disappeared in about four weeks (Fig. 3, *D*) and the patient's course since has been without complication. Fig. 3, *E* shows the status of the patient in March, 1948, one year after operation.

All the remaining cases in the resection group came to operation with marked reduction in sputum output, and practically dry in this respect. The postoperative courses were unusually benign and uneventful. No contralateral or ipsilateral spreads occurred in the immediate postoperative period, and no late spreads or exacerbations have been noted up to date. The Overholt face-down position was not used in these operations, and so is not a factor to account for low incidence of postoperative complications.

We have no untreated control series in which the patients were operated upon during the same time interval as this group of cases. However, the immediate postoperative results are in contrast with those of a small series of resections for tuberculosis done at Triboro Hospital between the years of 1942 to 1946. In this prestreptomycin group, 3 out of 21 lobectomies developed bronchopleura fistulas, empyema, and contralateral spread, of which the patients died from eight to nine months postoperatively. Two out of four patients with total pneumonectomies for destroyed lungs developed immediate postoperative contralateral spreads which resulted in death of the patients.

The next two groups of thoracoplasties should be considered together. The first group of 25 patients had multiple stage paravertebral thoracoplasties without preoperative or postoperative streptomycin. The second group of twenty-three patients had multiple stage thoracoplasties with preoperative and postoperative streptomycin.

The two groups are not exactly comparable, as they were not selected on a consecutive alternating basis. Since the streptomycin budget in a Municipal Hospital was not unlimited, its use in the individual case had to be restricted to certain rigid indications. Before streptomycin could be prescribed, each individual case was evaluated and passed upon by a committee of the chiefs of the medical and surgical services. Under these circumstances it was felt by the committee that in thoracoplasty cases the limited streptomycin available should be reserved for the substandard risk patients, and for those who, due to complications, might not have been able to undergo major surgery without streptomycin therapy.

The first group of 25 cases (Fig. 4) were considered standard thoracoplasty risks according to the usual methods of case selection. They underwent 73 stages of thoracoplasty. In 5 of these cases acute exudative spread occurred after first or second stages. Streptomycin therapy was instituted immediately on recognition of the complication and continued for 90 to 120 days in 4 cases. In the fifth case clearing was so rapid and complete that streptomycin was discontinued after twenty-eight days. In 4 of these cases it was found that the remaining stages could be completed after two to six weeks' delay instead of the usual wait of six or more months. The patients so treated have done well.

One death occurred in this group. A patient in his mid-forties died suddenly on the third day following an upper-stage thoracoplasty. Autopsy showed pulmonary embolism.

The roentgenograms in the following case are illustrative of a standard risk patient who had ipsilateral spread following an upper stage thoracoplasty.

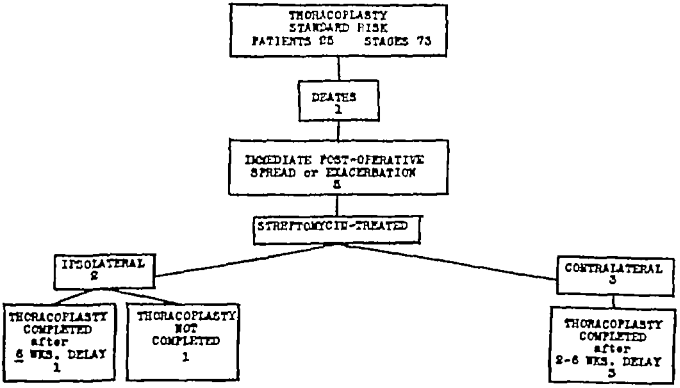


Fig. 4.

CASE 2.—A 40-year-old patient was admitted to Triboro Hospital for the first time in September, 1943, with bilateral upper lobe lesion and cavities in the left upper lobe. In spring, 1944, left pneumothorax was given for three months and abandoned because of ineffective collapse. July, 1944, the patient left the hospital against advice. In October, 1946, the patient was readmitted because of increased constitutional symptoms (Fig. 5, *A*). In mid-March, 1947, an upper-stage thoracoplasty was done without preoperative streptomycin. An acute exudative spread to the left lower lobe occurred immediately (Fig. 5, *B*). Streptomycin, 0.25 Gm. four times a day, was started and in five weeks sufficient x-ray resolution and remission of symptoms were noted, that it was deemed feasible to proceed with thoracoplasty (Fig. 5, *C*). The second stage was done on May 1 and the third stage on May 22, with uneventful postoperative course. Streptomycin was continued for 120 days. Sputum conversion with negative culture was obtained, and has been maintained to date (Fig. 5, *D*).

In the next group all 23 patients (Fig. 6) were considered substandard risks and were treated preoperatively and postoperatively with streptomycin. Eight had giant cavities or destroyed lungs with large daily sputum output. Five had contralateral pneumothorax or thoracoplasty. Three had previously active contralateral involvement, 2 had diabetes, and 5 others had large daily sputum output. After these patients were selected for possible thoracoplasty they were placed on streptomycin, 0.25 Gm. intramuscularly four times daily, observed until constitutional symptoms and sputum output were considered reduced to a minimum, and advantage was taken of this optimum time to

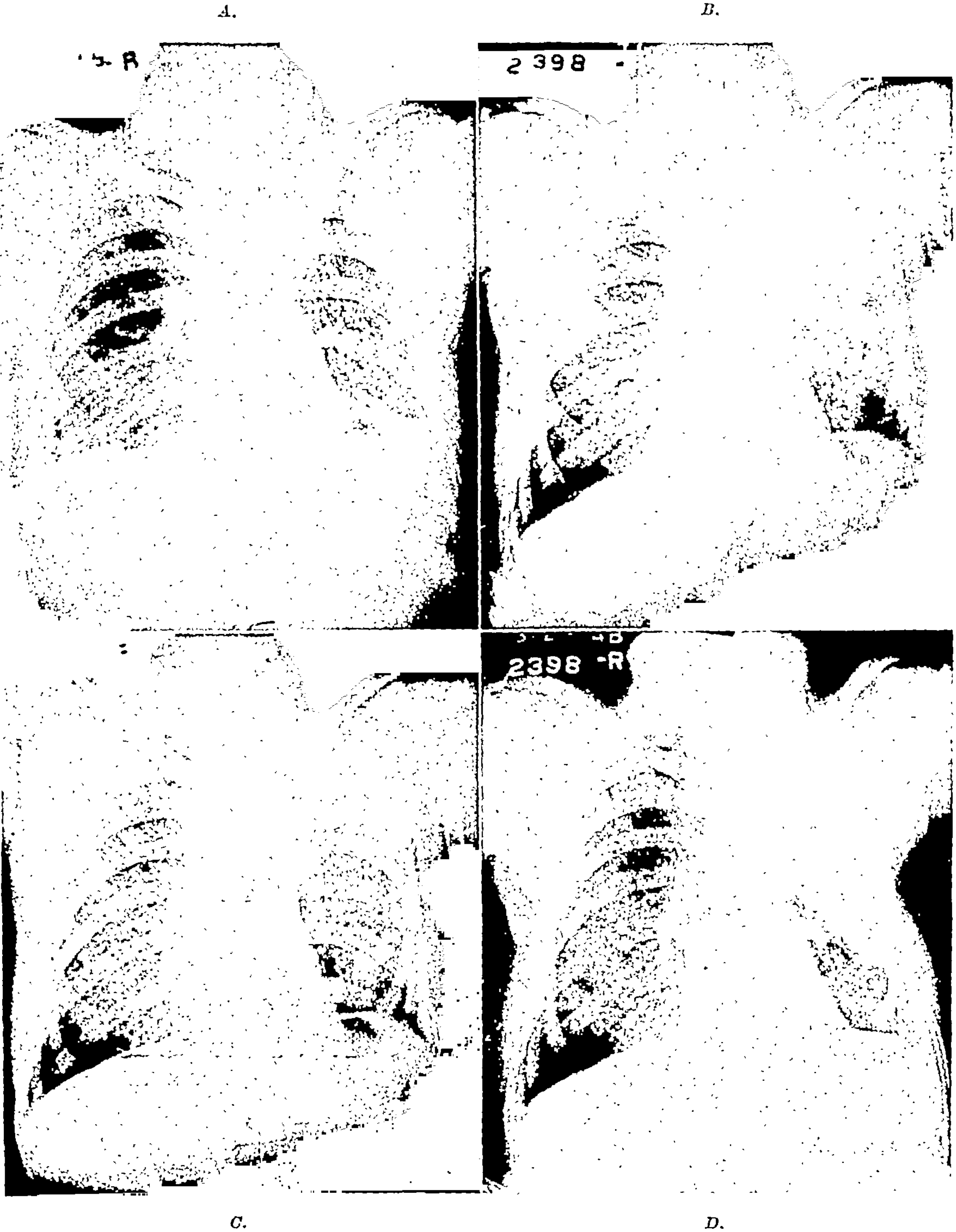


Fig. 5 (Case 2).—*A*, Immediately prior to left upper stage thoracoplasty. *B*, March 27, 1947, acute exudative spread in left lower lobe following upper-stage thoracoplasty. *C*, April 30, 1947, partial clearing of fresh exudative lesion in left lower lobe following one month streptomycin therapy. *D*, March 23, 1948, ten months after completion of thoracoplasty.

start the thoracoplasty. Thus the preoperative period of treatment varied. In the 8 cases with giant cavity or destroyed lung, the minimum preoperative treatment was twenty-eight days and the maximum forty-two days. In 2 of these cases concomitant laryngeal involvement cleared up completely during the preoperative treatment period. In all the cases of this sub-group of 8, streptomycin was continued postoperatively until 120 days of streptomycin therapy were completed. The contralateral pneumothorax and diabetic cases had a combined preoperative and postoperative total of 90 days' treatment. In the remaining cases the total treatment was 70 days each.

Fourteen of these patients had a pretreatment sputum output of 3 to 8 ounces per day. Nine had a sputum output of 1 to 3 ounces per day. In all cases there was a marked decrease in the sputum output, in some cases to 0 at the time the first stage was undertaken.

Twenty-two of these 23 patients underwent 71 stages of thoracoplasty with benign uncomplicated postoperative courses, and complete freedom from spread or exacerbation in all instances.

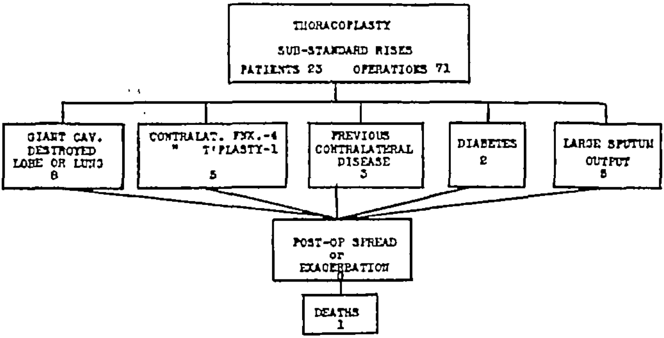
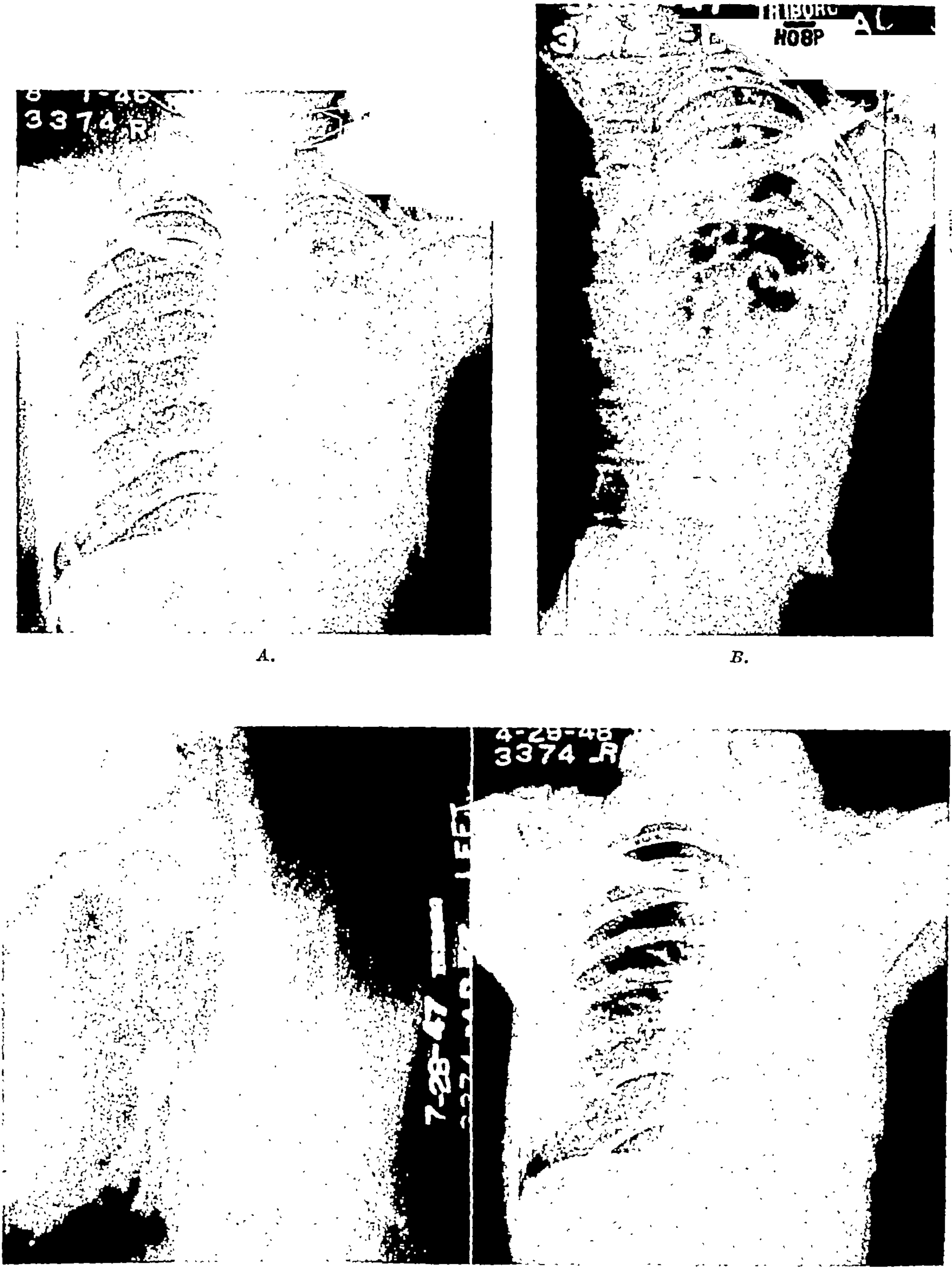


Fig. 6.

There was one postoperative death in this group. It was a sudden death on the ninth postoperative day following a second stage thoracoplasty. The *postoperative course had been benign and uncomplicated, and the patient was* apparently doing well. Autopsy was not obtained, so the cause of death was undetermined.

The x-ray films in Case 3 illustrate a substandard risk due to destroyed lung with multiple cavities and bronchiectasis, and large sputum output.

CASE 3.—An 18-year-old patient was admitted to Triboro Hospital in April, 1946, with an eleven-year history of pulmonary tuberculosis (Fig. 7, *A*). After one year of bed rest there was persistently elevated temperature, a daily sputum output of 8 to 9 ounces, heavily positive for tuberculosis, and mild laryngeal involvement with hoarseness. In April, 1947, decision was made to start collapse after preliminary streptomycin therapy. Pneumonectomy was contemplated, if thoracoplasty did not achieve arrest. The patient was placed on streptomycin, 0.25 Gm. four times a day, and response was dramatic. Within fourteen days the sputum output was reduced to less than 1 ounce per day, hoarseness and fever disappeared, and the patient began to gain weight. After twenty-eight days of streptomycin,



A. B.

C. D.

Fig. 7 (Case 3).—*A*, Aug. 1, 1946, preoperative. Multiple cavitation, destroyed lung. *B*, May 25, 1947, postoperative. First lower-stage thoracoplasty. *C*, July 28, 1947, postero-anterior tomograph about five weeks after final left upper stage. *D*, April 29, 1948, ten months post-thoracoplasty.

the lower first stage of a multiple stage thoracoplasty done from below upward was started (Fig. 7, *B*) and nine ribs were removed in four stages during May and June. Fig. 7, *C* is a roentgen tomographic view taken about four to five weeks after the last stage. Sputum conversion occurred soon after completion of surgery, and sputum has remained negative on culture up to the present time. Streptomycin was continued until a total of 120 days' treatment had been given. Fig. 7, *D* shows present status ten months postoperatively.

The next group (Fig. 8) comprises 12 cases of tuberculous empyema, 4 without demonstrable bronchopleural fistula, and 8 with bronchopleural fistulas.

The x-ray films in Case 4 illustrate treatment of a case of tuberculous-mixed empyema without bronchopleural fistula.

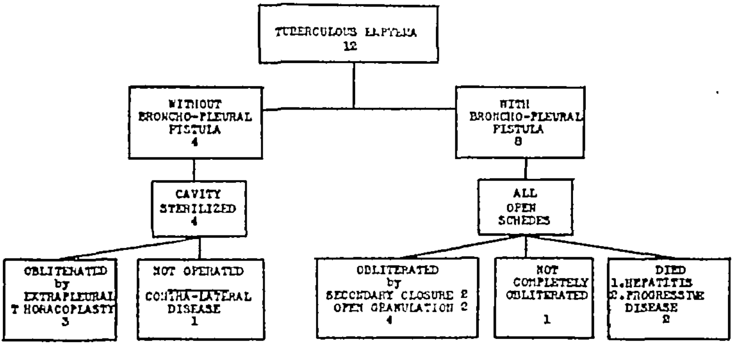


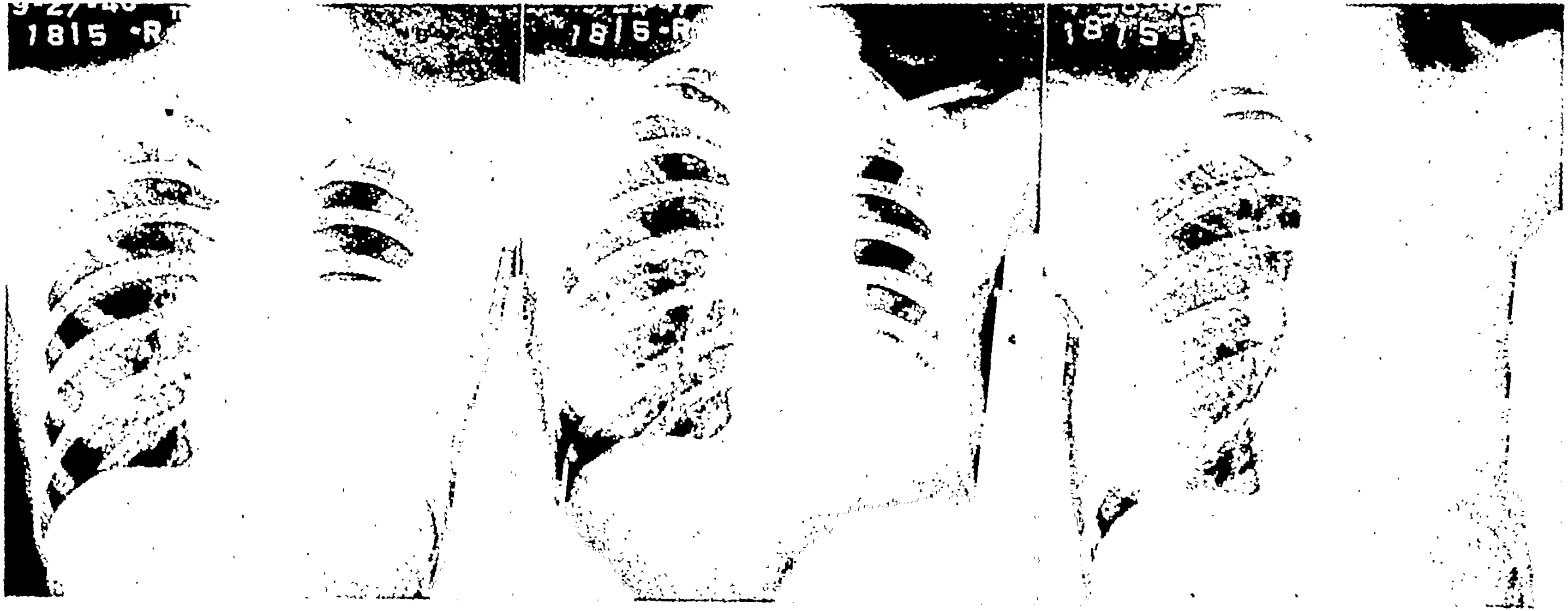
Fig. 8.

CASE 4.—A young white woman was readmitted to Triboro Hospital in September, 1946, with tuberculous-mixed infection empyema and pleurocutaneous fistulas (Fig. 9, *A*). Smear and culture showed tubercle bacilli and nonhemolytic streptococci. History dated back to 1939, with cavity in the left upper lobe treated by pneumothorax continuously. There was complete collapse of the left lung with bronchostenosis and persistently negative sputum. No bronchopleural fistula could be demonstrated.

After admission, twice-weekly thoracentesis with intrapleural instillation of 50,000 units of penicillin in 100 c.c. of saline rendered the pus free of streptococci but not of tubercle bacilli.

In the latter part of May, 1947, intrapleural streptomycin was started. Twice weekly the pus was evacuated by thoracentesis, and 1 Gm. of streptomycin diluted in 100 c.c. of saline was instilled. In a very short time the previously thick pus became thin and serous. After six weeks' treatment, fluid did not reform, and cultures for tubercle bacilli were sterile. The pleurocutaneous fistulae closed and in three months' time the patient gained thirty pounds in weight (Fig. 9, *B*). Subsequently a multiple stage thoracoplasty was done, and the left pleural space obliterated without resort to Schede operation (Fig. 9, *C*).

The three remaining patients in this group were treated with thoracentesis three times weekly. After evacuation of all fluid possible, 0.5 Gm. streptomycin diluted in 100 c.c. of saline was introduced into the empyema space. One patient had this treatment for ninety days before sterility was achieved; another for only twenty-two days. These three patients did not receive parenteral streptomycin. Streptomycin levels in the pleural fluid at forty-eight



A. *B.* *C.*

Fig. 9 (Case 1).—*A*, Sept. 27, 1946, tuberculous-pyogenic empyema, left. *B*, Sept. 24, 1947, after sterilization of empyema cavity with intrapleural penicillin and streptomycin. Prethoracoplasty. *C*, April 28, 1948, five months post-thoracoplasty.

to seventy-two hours after introduction of the drug varied from 10 to 160 millimicrograms per cubic centimeter. Simultaneous blood levels ranged from 5 to 10 μg irrespective of the pleural fluid concentration.

The empyema spaces in these three cases were rendered sterile and then obliterated by extrapleural thoracoplasty without drainage.

In the fourth case simultaneous parenteral streptomycin was given for ninety days because of extensive contralateral disease. The empyema space *was sterilized, but the contralateral disease did not improve sufficiently to* warrant thoracoplasty for obliteration.

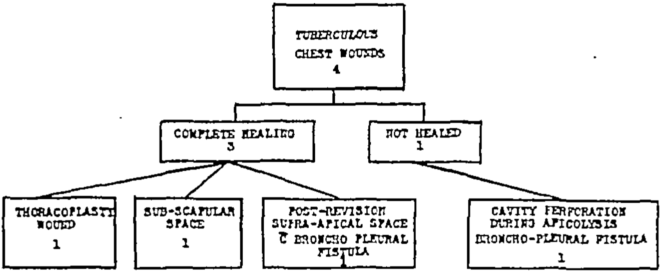


FIG. 10.

The 7 cases of tuberculous-mixed empyema with bronchopleural fistulas were all old cases that had residual empyema spaces after multiple stage Schede thoracoplasties. The treatment was to unroof surgically the residual space and leave it widely open. In two cases the thick infected fibrous plaque over the visceral pleura was decorticated without further mobilizing of the lung. These surgically exposed spaces were treated with streptomycin applied locally. *One gram of crystalline streptomycin was thoroughly mixed with 4* Gm. of dry plasma powder. The wounds were liberally dusted with this mixture daily. No parenteral streptomycin was given. Dramatic healing was achieved with relatively small amounts of the drug in a very short time. The average amount used was from 14 to 28 Gm. for the entire treatment. Healing occurred in from two to five weeks with clean, granulating, shrinking wounds, and no pus formation at any time. In 4 cases complete healing was achieved by this method; in one case healing was not complete. One patient died of hepatitis, and one of progression of disease during treatment.

Blood levels were not demonstrable in the patients treated by topical application.

The next group of four tuberculous infected chest wounds, tabulated in Fig. 10, were treated parenterally and topically with streptomycin. In two postoperative tuberculous infected wounds, successful secondary closure and complete healing were achieved. In a third case, a tuberculous infected chest wound was due to cavity perforation following revision of a thoracoplasty. The bronchopleural fistula closed and the wound healed to the surface by granulation. In the fourth case, resulting from cavity perforation occurring during apicolysis as a preparation for plombage, a bronchopleural fistula and tuberculous infected supra-apical space are still present. Streptomycin treatment was started, but had to be abandoned immediately because of extreme toxic sensitivity.

DRUG TOXICITY

One patient showed extreme sensitivity to the drug, and its use had to be abandoned. Only one patient developed vertigo of a significant degree after receiving 28 Gm. Seven patients showed slight toxic symptoms, such as headache and nausea. In these cases treatment was immediately discontinued for seven to ten days and then resumed, first with 0.5 Gm. as a daily dose and later, if no toxic signs recurred, the dose was increased to 0.75 Gm. daily. In 5 such cases treatment could be continued without any further toxic symptoms.

SUMMARY

Our experience with streptomycin as an adjunct in the surgical treatment of pulmonary tuberculosis in the Triboro Hospital during the year 1947 is presented. The results in 65 cases of pulmonary, pleural and chest-wall tuberculosis treated with streptomycin are summarized, and case histories typical of each group are cited. Twenty additional thoracoplasty patients untreated with streptomycin are included as controls. The efficacy of preoperative and postoperative streptomycin treatment in the prevention of postoperative complications in pulmonary resection for tuberculosis and thoracoplasty is evident. Beneficial effects of topical application of the drug in combination with open operations for bronchopleural fistulas and residual tuberculous empyema spaces are outlined. Dosage and mode of administration of the drug, and toxic reactions, are reviewed.

CONCLUSIONS

In our experience on the surgical service of Triboro Hospital as illustrated by the series of 85 cases presented herewith, streptomycin has been a most valuable adjunct in the surgical treatment of pulmonary tuberculosis, and has proved efficacious for the following indications:

1. Preoperatively and postoperatively for all pulmonary resections and intrapleural surgery on tuberculosis patients.
2. Preoperatively and postoperatively for all thoracoplastics considered substandard risks, or with complications such as contralateral pneumothorax, diabetes, etc.
3. For acute exudative postoperative spread, where streptomycin has not been used prophylactically.
4. Intrapleurally for pure tuberculous empyema without bronchopleural fistula.
5. In combination with open Schede thoracoplasty for tuberculous-mixed empyema with bronchopleural fistula.
6. In the infected chest wounds and sinuses.

(See discussion on page 55.)

THE ROLE OF STREPTOMYCIN IN THE SURGERY OF PULMONARY TUBERCULOSIS

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DETROIT, MICH.

IN THE past year, 800 patients have been treated with streptomycin at Herman Keifer and The Maybury Sanatorium. About 300 more have been treated at our other sanatoriums. It was our intention to give, at this time, *a detailed statistical report of our results in this series*, but this proved to be wishful thinking, and impossible of accomplishment. We can, however, give a general summary of our observations to date.

We shall confine this preliminary report to the patients at the Maybury Sanatorium who have received streptomycin for pulmonary tuberculosis only (either with or without collapse therapy or other measures), and to those at Herman Keifer Hospital in whom major surgical procedures have been contemplated or have been completed.

Patients given the drug were in the follow groups:

> Group 1. Those in whom we hoped that collapse or other surgical measures could be avoided or reduced in amount.
>
> Group 2. Those in whom surgical procedures (contraindicated because of the patient's condition, extent of disease, etc.) could be made possible through streptomycin.
>
> Group 3. Patients who received the drug as a prophylactic measure against spreads following surgical and collapse procedures, or to clear these spreads if they occurred, and to make the operation possible earlier.
>
> Group 4. Patients with proved or suspected tracheobronchial disease.

We have had streptomycin available in sufficient quantities for extensive trial only since the autumn of 1947, and most of it since January, 1948. It is obvious, therefore, that it is too early for definite, reliable statistical analysis. Many patients have not yet finished the course of treatment, and others have had it too recently to report end results. We have, however, been forced to some very definite conclusions regarding the merits of the drug because the whole course of the surgical management of pulmonary tuberculosis has, in our clinic, been revolutionized since its use was begun.

In Group 1, composed chiefly of patients with early, minimal and moderately advanced disease, we have found that streptomycin has decreased the

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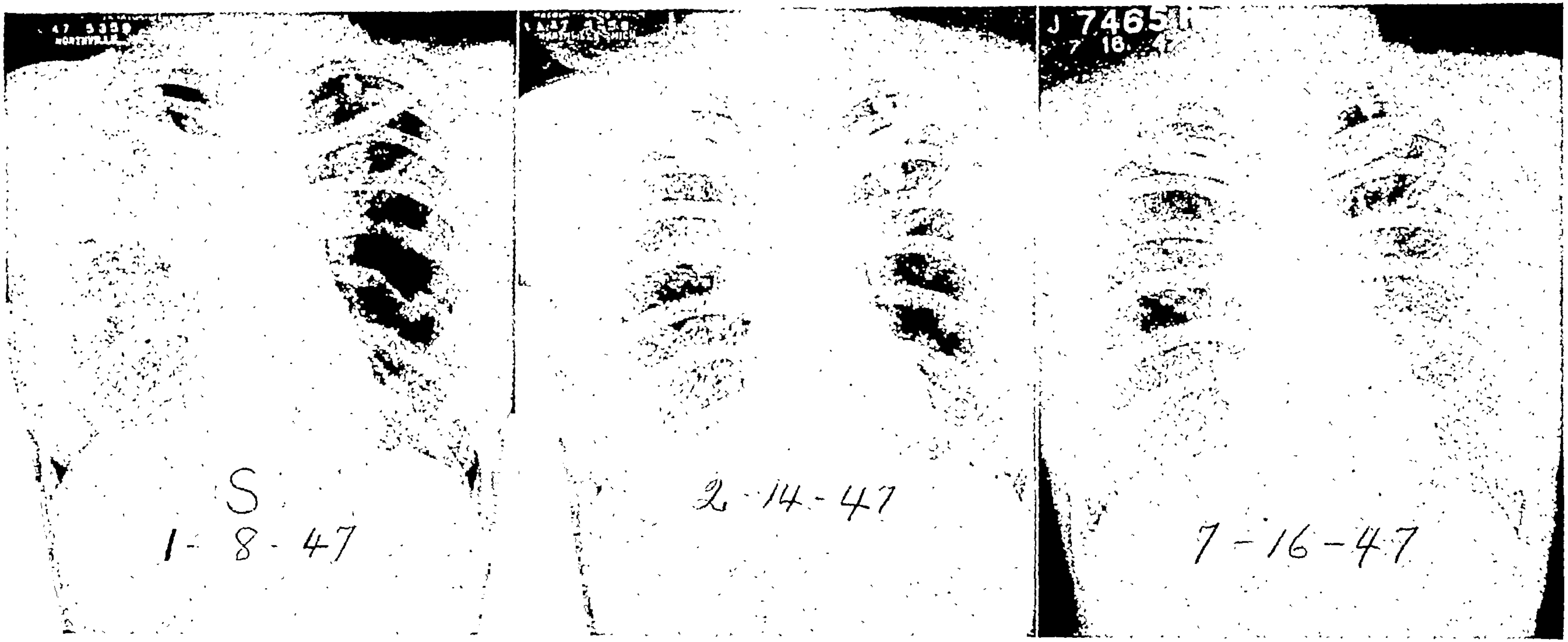
From the Herman Keifer Hospital, Detroit, Mich.; William H. Maybury Sanatorium, Northville, Mich.; Department of Surgery, Wayne University-College of Medicine, Detroit, Mich.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.



A. *B.* *C.*

Fig. 2.—Extensive disease with multiple cavitation and positive sputum in a very ill patient. *A*, Appearance of chest before treatment; *B*, appearance one month after treatment with streptomycin; *C*, appearance six months after start of treatment.

In spite of our stated middle-of-the-road attitude, in this group we have tended, in patients with extensive, soft disease with cavitation and for whom thoracoplasty or resection was deemed advisable before streptomycin, to perform these operations in spite of marked clearing. Whether this is the proper

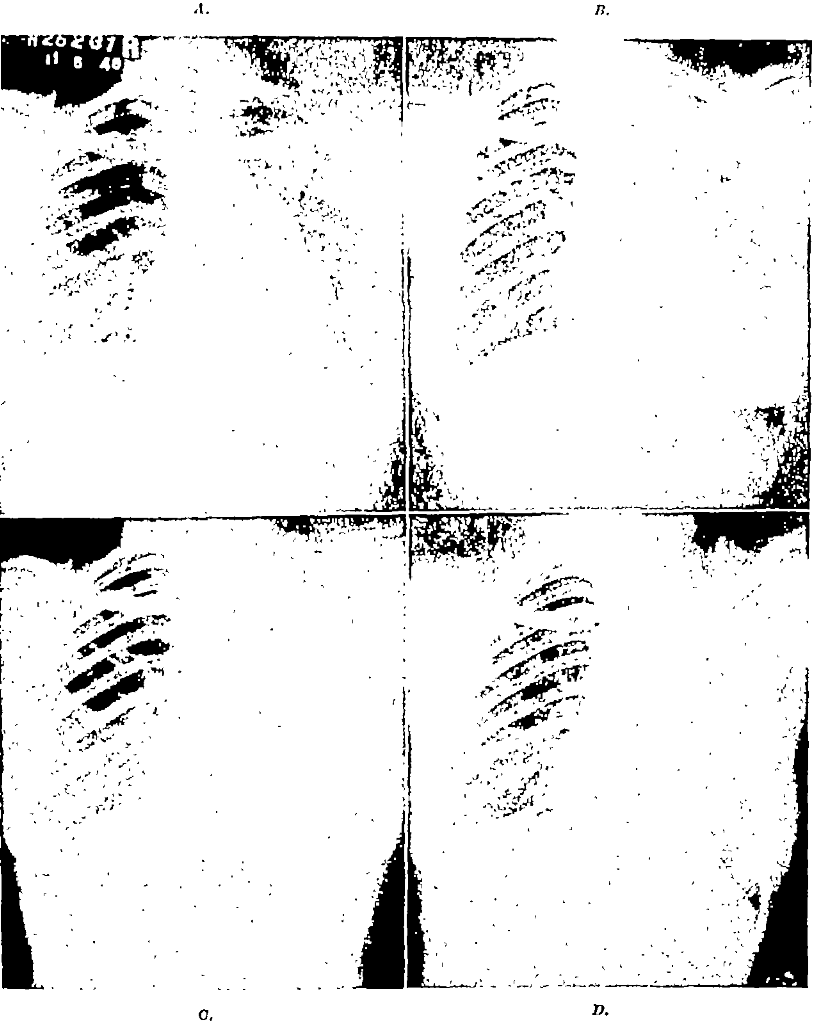


Fig. 3.—Intestinal tuberculosis in a very ill patient, seven months pregnant; temperature 103° F. *A*, Appearance of chest upon admission; *B*, appearance of chest after spread; *C*, right lung cleared under streptomycin; *D*, appearance following thoracoplasty.

course to follow can be determined only after much more time has elapsed and our experience broadened. In fact, what the future holds for all patients who have had streptomycin must await further observation.

In Group 2, we have found that the number of patients in whom surgical procedures (especially thoracoplasty) were possible was doubled by the administration of streptomycin. Many lesions, seen before administration of the drug, were so extensive and of such character that collapse measures could not be performed. Also, the condition of many patients was too grave, and there were complications such as gastrointestinal, peritoneal, pelvic tuberculosis contraindicating surgical procedures. Streptomycin is markedly effectual in these complications, and after they have subsided and sufficient clearing of the lesion has taken place, surgical procedures may frequently be completed with expectancy of good results. We have often seen patients extremely ill, with high temperature and dyspnea (some almost moribund and in oxygen tents), in whom the temperature became normal rapidly, the oxygen tent was removed, and the patients continued to improve making surgical procedures, with good results, possible later.

Group 3 somewhat overlaps Group 2, but will be considered separately. This group includes patients in whom major procedures are contemplated where soft lesions exist on the operation side, or an unstable lesion is present in the contralateral lung. Streptomycin is used here to prevent contralateral spread, and to clear or protect the contralateral lesions during and after the surgery. In Negroes and others with known lack of resistance, the use of the drug here is imperative. We are now operating on much softer lesions earlier and have observed fewer spreads since we began its use. We now believe that in all patients undergoing major surgical procedures it should be used prophylactically. Group 3 also includes those patients in whom a spread has occurred during or immediately following these operations regardless of previous streptomycin. It is our experience that these spreads clear much more readily with the drug, and with a marked decrease in the number of collapse measures necessary to assist them in doing so. The administration of streptomycin previously has not changed this observation. We have repeatedly restarted the drug with the same result as in those patients who have not had it. These patients obviously had not had a sufficient amount of the drug before operation. When so-called spreads occur, it is important, for statistical purposes, to distinguish between new, fresh lesions and reactivation of old lesions (or autotuberculinization) which are noted for their rapid clearing. A review of old roentgenograms is usually necessary to make this distinction. There can be no doubt that, in this group of patients, many months of hospitalization are saved. It is most probable that, in the future, marked reduction in the financial burden to the family or community will be achieved.

In Group 4, there is no question about the results in proved ulceration. These often heal as if by magic soon after the drug is started. The number of bronchoscopies performed for these lesions has been strikingly reduced. Prolonged treatment with silver nitrate application is no longer necessary.

Bronchoscopy is now done for diagnosis, and again after streptomycin therapy, the latter being virtually unnecessary, however, except for statistical purposes because it is so rare not to find ulcers healed after streptomycin therapy. It is our observation, however, that there is often much endobronchial ulceration, beyond the vision of the bronchoscope, which is the cause of atelectasis, blocked cavities, and positive sputum. If patients suspected of having such lesions are given streptomycin, with early and marked clearing of the atelectasis *and reduction in the size of the cavities, we can be sure that the diagnosis* was correct, and that the bronchi have again become patent. However, if the results are negligible, we can presume that the condition is either healed stenosis or parenchymal disease. Because sometimes it is difficult to differentiate between atelectasis and parenchymal disease by roentgenogram, we feel that some of the excellent results sometimes reported for old fibrotic lesions were probably in reality atelectasis (Fig. 4).

As stated earlier, we find it impossible, at this time, to break down this series in detail and evaluate results with any degree of accuracy. However, during *the year beginning in March, 1947, there were 89 first stage thoraco*plastics performed without the use of streptomycin. Only sporadically was the drug used until autumn of that year. During the same year, however, streptomycin was given to 101 patients to prepare them for thoracoplasty. Following its administration in this group, 20 were found no longer in need of it. These 20 were classified, before treatment, as follows: favorable, 10; unfavorable, 5; hopeless, 5. There are 50 patients now ready and waiting for operation. This group was classified before streptomycin as: favorable, 9; unfavorable, 16; hopeless, 25. We have found that there are fewer spreads following tho*racoplasty, and also fewer residual cavities. This is explained by the marked* effectiveness of streptomycin in blocked cavities which are often displaced but unchanged in size; after one or two stages of thoracoplasty, these frequently close after streptomycin. The drug should be used, however, before rebridged bone occurs to prevent approximation of cavity walls and healing. In this regard, it must be kept in mind that the size of a cavity revealed by roentgenogram does not at all represent the amount of destruction of lung parenchyma. Cavities (especially blocked ones) have a tendency to balloon, and give a distorted idea of the amount of pathology present. Frequently, it is impossible to determine whether blocked or partially blocked cavities exist. Therefore, it seems obvious that streptomycin should be used as a prophylactic measure in all patients undergoing thoracoplasty.

There were twenty-three patients who received streptomycin prior to resection. Nine of these had extensive tracheobronchial disease or unstable lesions in the contralateral lung which made resection impossible prior to streptomycin. It was given to the remainder as a prophylactic measure. There was one late empyema, and one death occurred from hemorrhage, but no other untoward incidents occurred from operation in this group. In twenty patients, streptomycin was used during the course of decortication because of pleural involvement, etc., and no complications arose in this group following operation except one bronchopleural fistula. Their postoperative course, however, was smoother, and pleural reactions were less marked, and cleared more promptly.

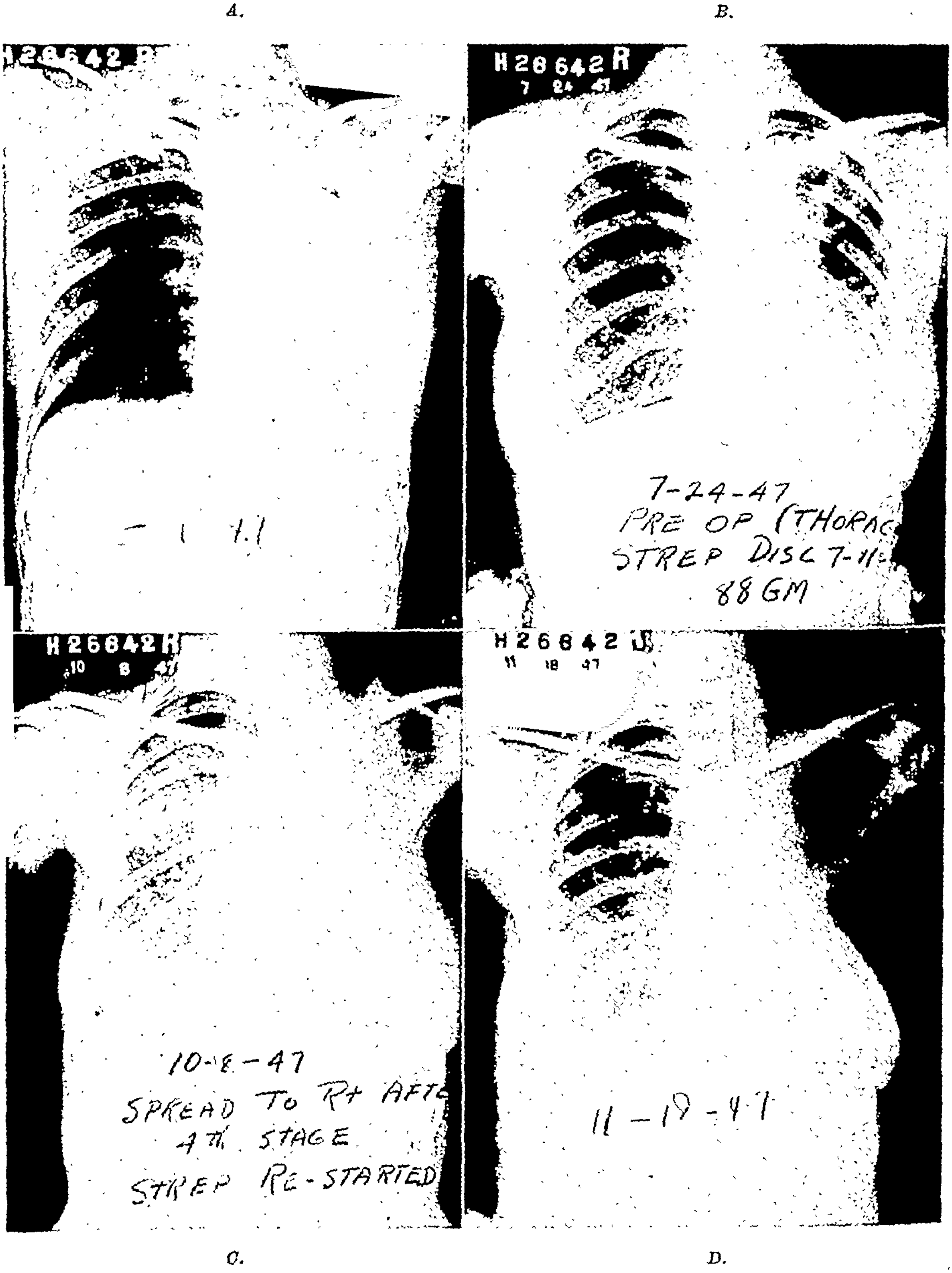


Fig. 4.—*A*, Film before streptomycin; *B*, reveals marked clearing two months after streptomycin—atelectasis gone, cavity remaining; *C*, film showing spread following thoracoplasty in spite of previous streptomycin; *D*, clearing after restarting streptomycin.

At the Maybury Sanatorium, thirty-three patients who were thought to need collapse measures before streptomycin did not need them afterward. Twenty-six others who were thought to need major procedures needed only minor ones after streptomycin therapy. Sixty-three, in whom collapse or surgery was impossible before use of the drug, were able to have these procedures. *In sixty-seven, there was no change in the pre- and post-treatment* recommendations. In this group, there was considerable improvement in the lesions and symptoms, in most patients, and they were made better candidates for the procedures recommended. Fourteen were given the drug for fresh spreads. All of these cleared without the addition of other collapse measures. In thirty-three, no collapse was possible before or after treatment. This group can be classified as failures. In the remainder of the patients, it is too early for conclusions.

We have attempted not to give tiresome and confusing figures of statistics, but to show, in general, what in our experience streptomycin can be expected to accomplish in the surgical management of pulmonary tuberculosis, and to suggest a somewhat routine course for its application.

As would be expected, our results were most striking in soft mixed, and most recent lesions. However, occasionally, in apparently old, fibrotic lesions, excellent results have been obtained. In almost *all* patients, some clearing of the lesions and clinical improvement have been noted. One of our great problems is to know what to do with these "old chronics" in whom the outlook seems hopeless. If we give streptomycin to them as a last resort, we shall probably tend to put the drug into disrepute. Relatives, who are told that the patient's condition is hopeless, however, will always feel better if they know that everything possible has been tried. Even in terminal patients, it is *probable that the temporary symptomatic improvement, the feeling of well-*being, decreased cough, and lessened discomfort make administration of the drug worth while. At least, their last days are made easier. We feel that it is a doctor's function to get people well if possible, but if this cannot be done, he must at least make them as comfortable and as happy as lies within his power. Streptomycin does so many wonderful things when it is properly employed that we do not believe its prestige will be seriously damaged following this philosophy.

In our experience, the results of streptomycin therapy, in properly selected patients, have frequently been so amazing that there is an inclination to be overzealous in our attitude toward it. We believe, however, that our policy should be one of conservatism for fear that charlatans and quacks, and those unfamiliar with its use and complications, will employ it indiscriminately, and cause more heartache and suffering than can be offset by their results. Even at the present time, it is being used by some men as a substitute for bed rest and the proper collapse measures. These men employ it in ambulatory patients, with positive sputum, who are living at home with their families or others, thus spreading the disease to many innocent victims. Meanwhile, the patients are receiving inefficient and inexcusable treatment. It cannot be emphasized too often that streptomycin is not a substitute for but is an adjunct to bed rest and proper collapse measures.

One will not find perfect accord regarding the efficacy of the drug even among the best men in the profession. Those who are unfortunate enough to work in hospitals or sanatoriums where most patients have lesions, of the old chronic, fibroid type will not be enthusiastic about the use of streptomycin, but it must be remembered that all "old chronics" have become so, in most instances, because proper treatment was not instituted earlier. They were all, at one time, patients with soft, early lesions readily amenable to treatment.

One cannot conclude a discussion of streptomycin without dwelling on the complications which sometimes follow its use. In the early days, excessive amounts of the drug were given, and there were many serious and permanent complications. Eighth nerve involvement, vestibular involvement, kidney damage, skin eruptions, etc., were common. Great fear was expressed that the drug would fall into disrepute. At the present time, although we are not sure exactly how much of the drug is necessary to control disease in a given patient, we do know that much smaller doses, given once a day, will accomplish the desired result, in most instances, with far less danger of complications. At the Maybury Sanatorium, we are giving 1 Gm. once each day for six weeks. At the Herman Keifer Hospital, we give ½ Gm. once each day for twelve weeks. We are not certain which is the better method. Possibly much smaller dosage will suffice in many instances. With our present dosage, we have noticed a marked decrease in complications. Permanent significant damage virtually does not exist, and while frequently there are encountered vestibular disfunction and skin eruptions, these usually subside with the withdrawal of the drug. It can usually be started again later without repetition of these manifestations. Where expected results were not obtained during routine treatment, we have occasionally increased the dosage or prolonged its use.

This program has sometimes given results not obtained with the previous regime. There is a lot we do not know about streptomycin, but our knowledge is ever increasing. We are sure that streptomycin is the greatest single contribution we have had to date to aid us in our efforts to eradicate tuberculosis.

REFERENCES

1. Hinshaw, C. H.: Personal communication.
2. Feldman, W. H.: Personal communication.

(See discussion on page 55.)

EXPERIMENTAL AND CLINICAL STUDIES OF THE ROLE OF STREPTOMYCIN IN THE PLEURAL CAVITY

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STREPTOMYCIN was first described by Waksman[1] in 1944. In 1945 Feldman[2] demonstrated that streptomycin exerted a protective effect in experimental tuberculosis in the guinea pig. Hinshaw[3] later reported beneficial effects on human tuberculosis treated with streptomycin.

Various investigators have studied the absorption of streptomycin injected intravenously and intramuscularly. For example, Adcock[4] has shown that 100,000 units (0.1 Gm.) of streptomycin given intravenously immediately produced a streptomycin blood level of 16 micrograms per cubic centimeter; this level fell quickly. At the end of one hour the streptomycin blood level was 5 micrograms per cubic centimeter or less. Zintel[5] gave 600,000 units (0.6 Gm.) of streptomycin intravenously and immediately produced a blood level of approximately 33 micrograms per cubic centimeter. After two hours there was a blood level of nearly 20 micrograms per cubic entimeter. At the end of six hours the blood level had fallen to zero.

One hundred thousand units (0.1 Gm.) of streptomycin given intramuscularly produced a maximum streptomycin blood level of approximately 7 micrograms per cubic centimeter one hour after injection. The blood level fell gradually over a ten-hour period to 1 microgram per cubic centimeter. Zintel employed 600,000 units (0.6 Gm.) of streptomycin intramuscularly, which caused a gradual rise to a maximum blood level of about 20 micrograms per cubic centimeter in three hours. This level fell gradually to 10 micrograms per cubic centimeter at the end of six hours.

Experimental observations by Stebbins,[6] on dogs, indicated that 100,000 units (0.1 Gm.) of streptomycin given intravenously produced an immediate blood level of 20 to 30 micrograms per cubic centimeter. Four hours later the blood level had fallen to 2 to 3 micrograms per cubic centimeter.

Since the beneficial effects of streptomycin on human tuberculosis have been demonstrated, it is reasonable to assume that the local use of streptomycin in the human pleura for tuberculous effusions or tuberculous empyema might be desirable.[7] Moreover, the local use of the antibiotic, after pulmonary resections for tuberculosis, could be expected to reduce the incidence of tuberculous empyema. This investigation was undertaken to determine whether or not streptomycin injected into the pleural cavity might produce deleterious effects on the pleura serosa and to determine the absorption rate of streptomycin from the pleural cavity.

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METHODS

Dog Experiments.—Nine apparently healthy mongrel dogs weighing about 8 kilograms were used. There were no apparent wound infections nor any deaths.

Intravenous nembutal plus intratracheal ether anesthesia was used. With aseptic precautions the left or right pleural cavity was entered by resecting a piece of rib 3 to 4 cm. in length. One hundred cubic centimeters of isotonic saline were then placed in the pleural cavities of three dogs. One hundred cubic centimeters of isotonic saline containing 0.5 Gm. of streptomycin were placed in the pleural cavities of six dogs. The streptomycin was calcium chloride complex* and had been freshly dissolved. The pleura, muscles, and skin were closed with fine, interrupted silk sutures. Pleural fluid and blood samples were collected from the animals for streptomycin titer assay.

On the seventh postoperative day the wounds of all nine dogs were reopened. Biopsies of the pleura were taken from the pleura involved in the scar and from the pleura away from the scar. The gross appearance of the pleural cavities of the two series of dogs seemed the same. There were small adhesions of the lung to the pleura in a few of the dogs, but there were no adhesions in most of the dogs. The wounds were reclosed and the biopsies of the pleura were fixed in 10 per cent formalin for microscopic section and examination.

Human Experiments.—In twelve human patients 0.5 Gm. of streptomycin in 10 c.c. of saline was instilled in the pleural cavity at the close of a thoracotomy. The pleural cavities in these cases had been opened by resecting a rib, and various types of thoracic operations had been carried out. Some of the pleural cavities were drained by an intercostal catheter which was unclamped at various intervals after the instillation of the streptomycin. In all cases 100,000 units of penicillin in 10 c.c. of isotonic saline were installed along with the streptomycin. At various intervals postoperatively 5 c.c. of sterile clotted blood were withdrawn for streptomycin titer assay.

The sterile clotted blood samples were kept refrigerated until the assay was done. This varied from a few hours to a few days later. The method used was a broth dilution technique devised by Romansky.[8] Except as otherwise noted, whenever penicillin was present, penicillin antibiotic activity was destroyed by the addition of penicillinase to the broth culture tubes.

RESULTS OF THE DOG EXPERIMENTS

Absorption Studies.—The study on four dogs receiving 0.5 Gm. of streptomycin in the pleural cavities at open thoracotomy is summarized in Fig. 1. In three dogs, fluids taken from the chest immediately after the streptomycin had been instilled was found to contain 3,750 micrograms of streptomycin per cubic centimeter. Samples of pleural fluid were collected by thoracentesis from four dogs two hours after streptomycin had been instilled. These samples had, respectively, 100. 500, 375, and 1,650 micrograms of streptomycin per cubic centimeter. At the same time that this pleural sample was taken, venous blood was also taken for analysis. These levels were, respectively, 20, 20, 20, and 10 micrograms per cubic centimeter. Chest fluid taken from a dog twenty-four hours after injecting streptomycin contained no detectable streptomycin. Blood taken twenty-four hours after injection of streptomycin into the chest contained, respectively, 1 and 0 micrograms per cubic centimeter in two different dogs. A more complete absorption curve for streptomycin was obtained in another dog. Blood samples were collected one-half hour, four hours, eight hours, and twenty-four hours after placing 0.5 Gm. of streptomycin in the pleural cavity of the dog. These levels were, respectively, 25, 20, 5, and 0 micrograms of streptomycin per cubic centimeter. These data are illustrated in Fig. 2. Another absorption curve was determined by collecting blood samples at one hour, 7 hour and 24 hour intervals in another dog. These levels were, respectively, 25, 2.5, and 0 micrograms of streptomycin per cubic centimeter. These data are illustrated in Fig. 3. In all the dogs studied the absorption of streptomycin from the pleura was rapid.

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*Manufactured by Merck & Co., Inc., Rahway, N. J.

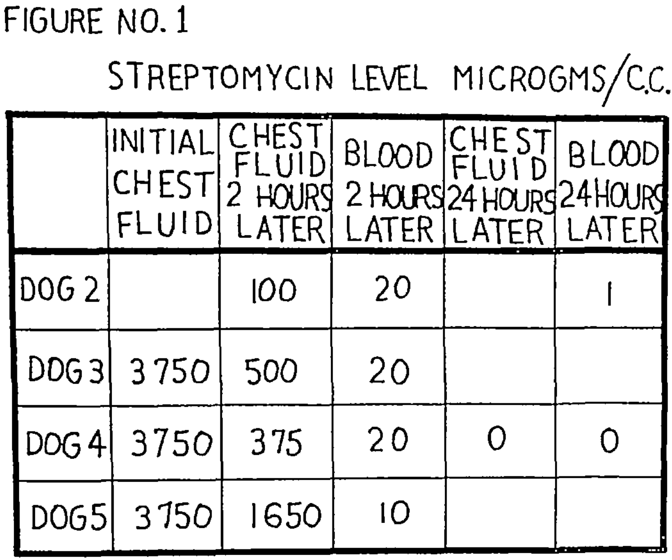

FIGURE NO. 1

STREPTOMYCIN LEVEL MICROGMS/C.C.

	INITIAL CHEST FLUID	CHEST FLUID 2 HOURS LATER	BLOOD 2 HOURS LATER	CHEST FLUID 24 HOURS LATER	BLOOD 24 HOURS LATER
DOG 2		100	20		1
DOG 3	3750	500	20		
DOG 4	3750	375	20	0	0
DOG 5	3750	1650	10		

Fig. 1.—Streptomycin absorption data from four dogs.

Pathologic Studies.—Microscopic sections were made of the biopsies of the pleura taken from the three saline control dogs and the six dogs receiving streptomycin. The pleurals taken away from the thoracotomy scar in the saline and in the streptomycin experiments are essentially the same. Giant cells and fibroblasts are seen in the pleural scars. It is apparent that these giant cells represent a foreign body response induced by the presence of silk sutures, since microscopic sections reveal no appreciable difference in pleuras which received saline or streptomycin.

RESULTS IN HUMAN EXPERIMENTS

There were twelve human cases studied. Six of these patients were considered to have unscarred pleuras, while in two cases the pleura was moderately scarred and in four the pleura was markedly scarred.

Unscarred Pleuras.—The first human study was conducted on a patient who had a resectable carcinoma of the esophagus and in whom the pleura seemed normal. On the first postoperative day 0.5 Gm. of streptomycin was injected into the pleural cavity through the intercostal drainage catheter. The catheter was then clamped off to permit absorption of the streptomycin. Venous blood samples were collected 1, 2, 6, and 8 hours later. The levels were 5, 5, 2.5, and 2.5 micrograms per cubic centimeter. These results are illustrated in Fig. 4.

The second human case was a patient who had a portion of the chest wall resected because one rib contained a metastasis from a thyroid carcinoma. The pleura seemed uninvolved. Samples were taken at 30 minutes, one, two, four, six, and eight hour intervals. The catheter was unclamped just after the second

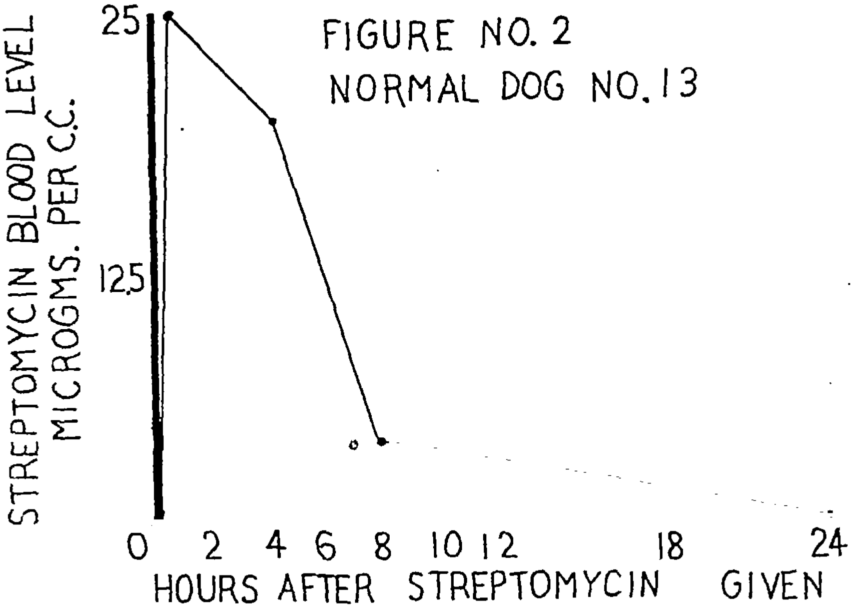

Fig. 2.—Streptomycin absorption from the pleura of a normal dog.

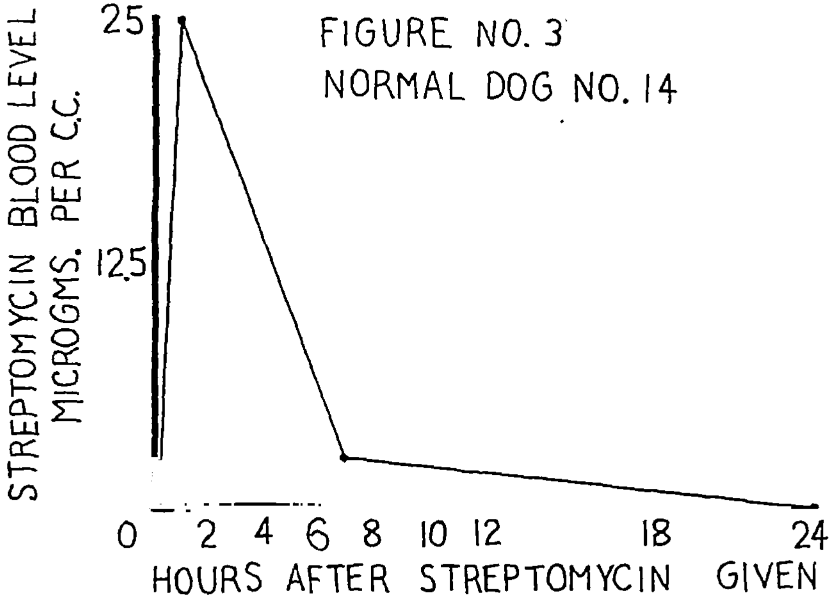

Fig. 3.—Streptomycin absorption from the pleura of a normal dog.

hour sample was collected. The levels were 25, 20, 5, 5, 2.5, and 2.5 micrograms per cubic centimeter. These data are illustrated in Fig. 5.

The third human study was done on a patient who had an inoperable carcinoma of the lung where the pleura was uninvolved and where no intercostal catheter was used. No penicillinase was available. Levels were taken at thirty minutes, one, two, four, eight, and twelve hours. The levels were 50, 37.5, 20, 10, 5, and 2.5 micrograms per cubic centimeter. These data are illustrated in Fig. 6.

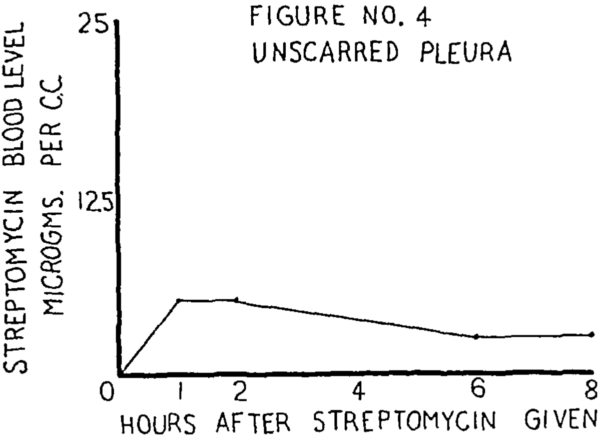

Fig. 4.—Streptomycin absorption curve from unscarred pleura, Case 1.

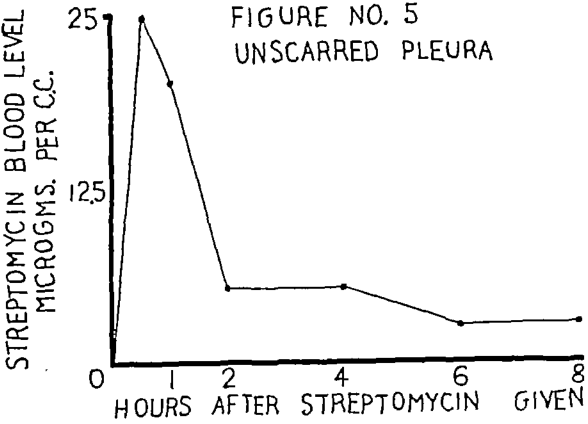

Fig. 5.—Streptomycin absorption curve from unscarred pleura, Case 2.

The fourth patient studied had an exploratory thoracotomy. Inflammatory nodes were found, and the pleura seemed normal. Blood levels were taken at thirty minutes, one, two, four, and six hour intervals. These levels were 12.5, 5, 5, 5, and 3.75 micrograms per cubic centimeter. These data are illustrated in Fig. 7.

The fifth patient studied had a mediastinal xanthoma removed. At the time of exploration the pleura seemed normal. Blood levels were determined

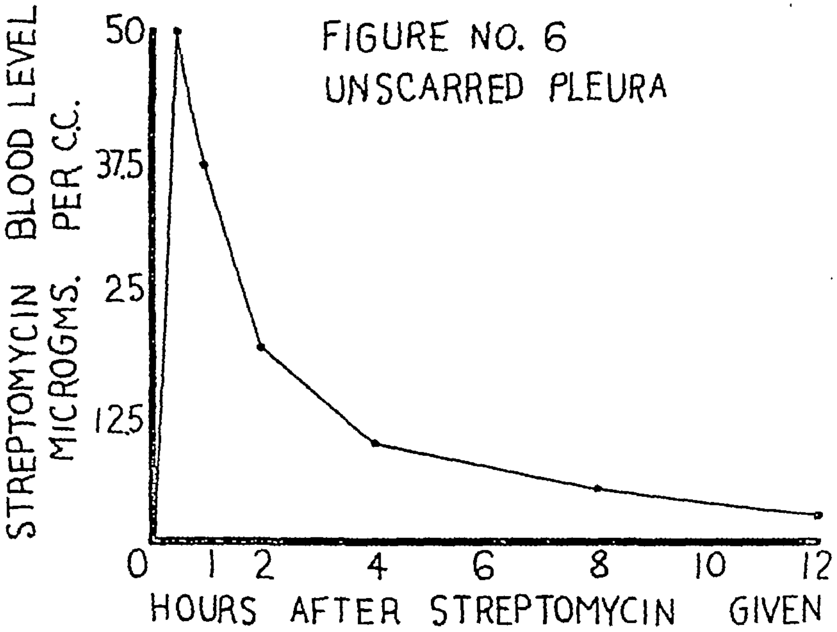

Fig. 6.—Streptomycin absorption curve from unscarred pleura, Case 3.

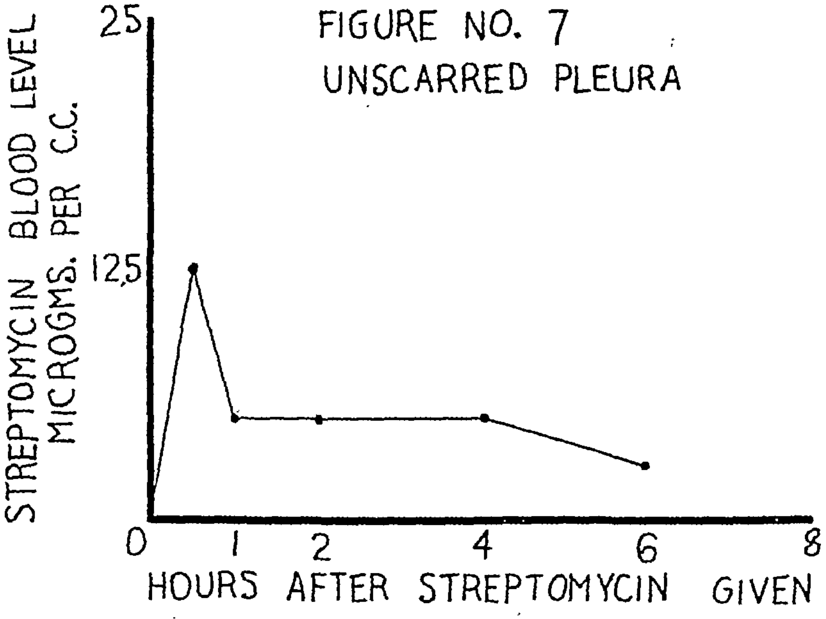

Fig. 7.—Streptomycin absorption curve from unscarred pleura, Case 4.

at thirty minutes, one, two, and four hour intervals. The levels were 25, 12.5, 10, and 5 micrograms per cubic centimeter. These data are illustrated in Fig. 8.

In the sixth case a thoracic exploration was performed. The pleura was found to be normal. Levels were taken at thirty minutes, one, two, four, and eight hours. The levels were respectively 25, 12.5, 10, 5, and 2.5 micrograms per cubic centimeter. These data are illustrated in Fig. 9.

Moderately Scarred Pleuras.—A moderately scarred pleura was found in a woman who had an open pneumonolysis performed for pulmonary tuberculosis.

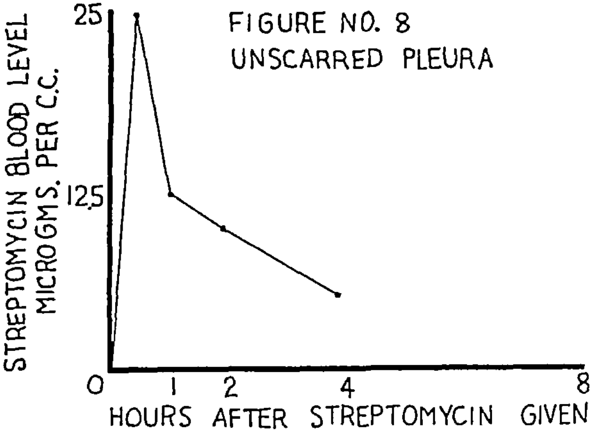

Fig. 8.—Streptomycin absorption curve from unscarred pleura, Case 5.

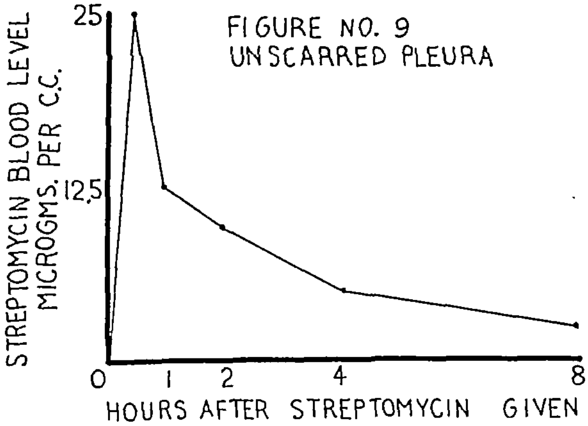

Fig. 9.—Streptomycin absorption curve from unscarred pleura, Case 6.

She had received 0.5 Gm. of streptomycin intramuscularly thirteen hours prior to operation. No intercostal catheter was used. No penicillinase was available. Blood samples were determined at thirty minutes, one, two, eight, and twelve hour intervals. The blood levels were found to be 22.5, 12.5, 12.5, 2.5, and 2.5 micrograms per cubic centimeters. These data are illustrated in Fig. 10.

The second patient who was considered to have a moderately scarred pleura had a left lower lobectomy and lingulectomy performed for bronchiectasis. There were a moderate number of adhesions present. An intercostal catheter was used. Blood samples were done at thirty minutes, one, two, four, and eight

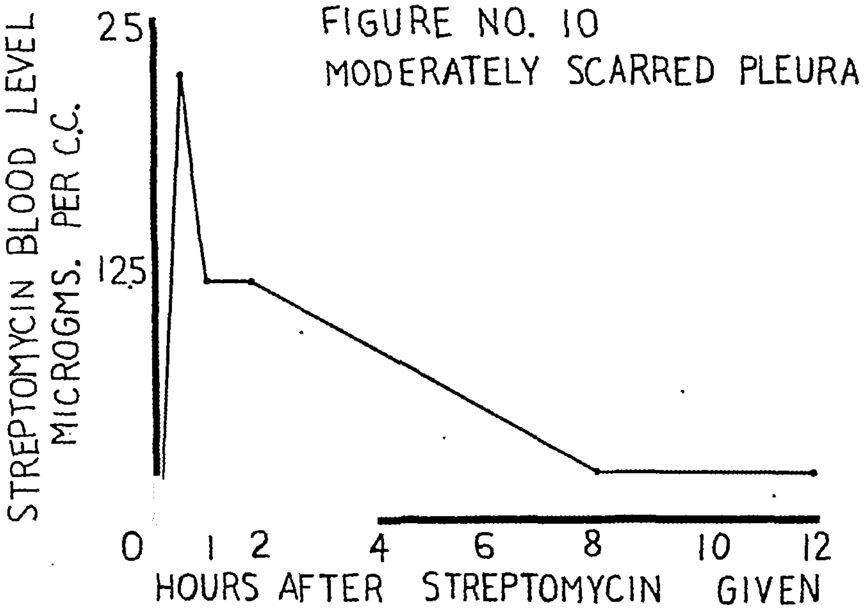

Fig. 10.—Streptomycin absorption curve from moderately scarred pleura, Case 7.

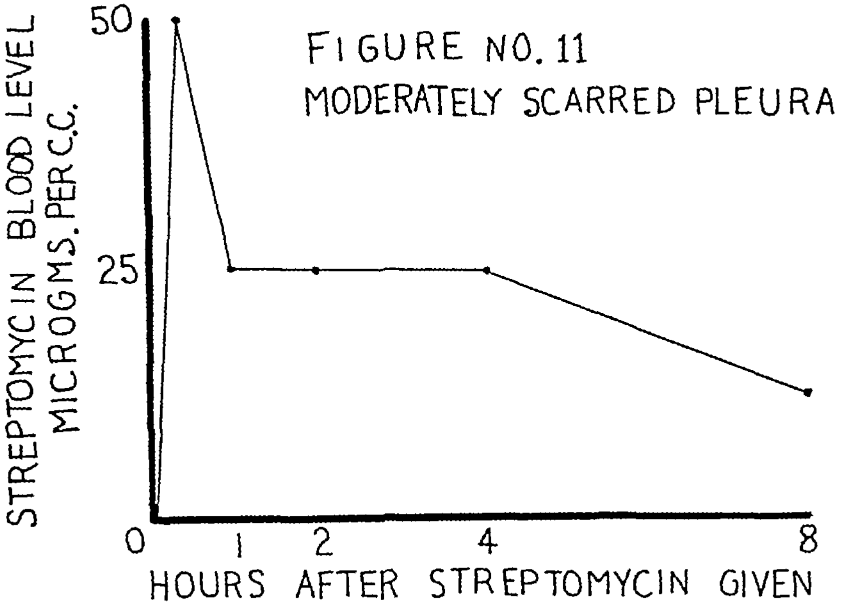

Fig. 11.—Streptomycin absorption curve from moderately scarred pleura, Case 8.

hours. The levels were found to be 50, 25, 25, 25, and 12.5 micrograms per cubic centimeter. These data are illustrated in Fig. 11.

Markedly Scarred Pleuras.—The first patient who was considered to have a markedly scarred pleura had a pneumonectomy performed for pulmonary tuberculosis. The patient had already had three stages of thoracoplasty performed and received streptomycin, 0.5 Gm., thirteen hours prior to surgery. There was no available penicillinase. Blood samples were withdrawn at thirty minutes, one, two, four, six, and eight hours. These samples were found to contain 12.5, 10, 5, 3.75, 2.5, and 1.25 micrograms of streptomycin per cubic centimeter. These data are illustrated in Fig. 12.

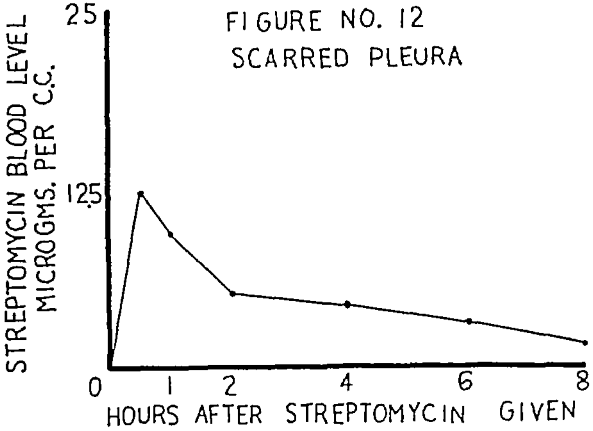

Fig. 12.—Streptomycin absorption curve from markedly scarred pleura, Case 9.

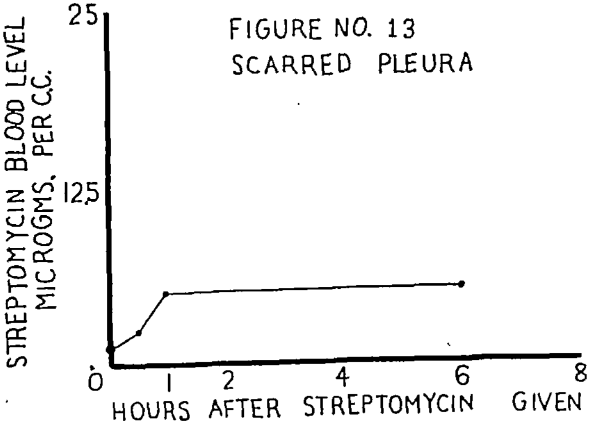

Fig. 13.—Streptomycin absorption curve from markedly scarred pleura, Case 10.

The second patient with markedly scarred pleura also had a pneumonectomy performed for pulmonary tuberculosis. She too received 0.5 Gm. of streptomycin about twelve hours before operation. Blood samples were withdrawn before injecting the streptomycin, and then 30 minutes, 1 hour and 6 hours later. The levels were 1.25, 2.5, 5, and 5 micrograms per cubic centimeter. These data are illustrated in Fig. 13.

The third patient having a markedly scarred pleura had a pneumonectomy for tuberculosis. Blood samples were withdrawn at thirty minutes, one, two, and four hour intervals. The blood levels in these samples were 25, 25, 10, and 5 micrograms per cubic centimeter. These data are illustrated in Fig. 14.

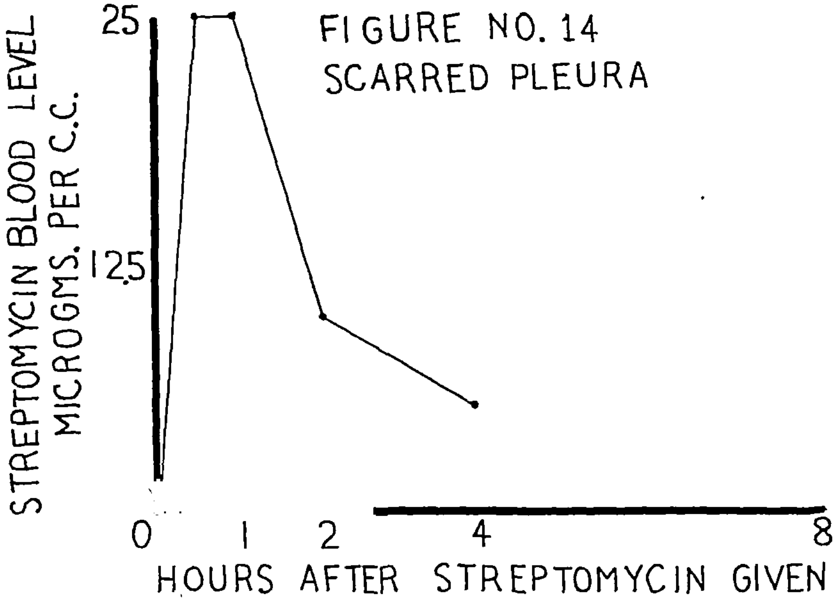

Fig. 14.—Streptomycin absorption curve from markedly scarred pleura, Case 11.

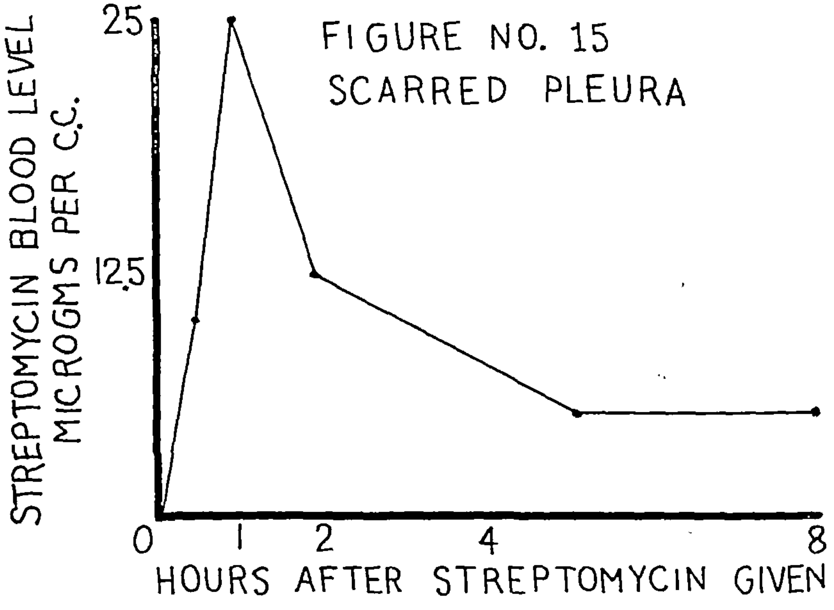

Fig. 15.—Streptomycin absorption curve from markedly scarred pleura, Case 12.

The fourth patient with a markedly scarred pleura had a pneumonectomy for carcinoma of the lung. The pleura was involved and was markedly scarred. Blood samples were withdrawn at thirty minutes, one, two, five, and eight hour intervals. These levels were found to be 10, 25, 12.5, 5, and 5 micrograms per cubic centimeter. These data are illustrated in Fig. 15.

SUMMARY

This paper describes experiments to determine the pathologic effect and the absorption rate of streptomycin from the the pleural cavity.

Operations were performed on nine dogs. Three of these dogs received 100 c.c. of saline into the pleural cavities, and then had a biopsy taken from the pleura seven days later. Six of the dogs received 0.5 Gm. of streptomycin in 100 c.c. of saline into the pleural cavities. Streptomycin assay studies were carried out on pleural fluid and venous blood. The pleura was biopsied seven days after injection.

The absorption rate of streptomycin from the pleuras of dogs was rapid and the maximum blood levels were reached in thirty to sixty minutes.

There were no apparent differences in the microscopic picture of the pleura from the animals receiving saline and the animals receiving streptomycin.

Twelve human patients received streptomycin intrapleuraly. These twelve cases can be subdivided into six cases of unscarred pleuras, two of moderately scarred pleuras, and four of markedly scarred pleuras. The absorption curves were similar in all three types. The absorption is rapid, being maximum usually in thirty minutes, and falls to low levels in six to eight hours.

CONCLUSIONS

No harmful effects were seen either in the gross or the microscopic picture of pleura removed from dogs seven days after the dogs received strepomycin in the pleural cavity.

The absorption of streptomycin from the pleura of dogs and human beings is rapid and high levels are reached.

Scarred pleuras seem to absorb streptomycin as well as unscarred pleuras.

REFERENCES

1. Schatz, A., Bugie, E., and Waksman, S. H.: Streptomycin: a Substance Exhibiting Antibiotic Activity Against Gram Positive and Gram Negative Bacteria, Proc. Soc. Exper. Biol. & Med. 55: 66, 1944.
2. Feldman, W. H., Hinshaw, H. C., and Mann, F. C.: Streptomycin in Experimental Tuberculosis, Am. Rev. Tuberc. 52: 269, 1945.
3. Hinshaw, H. C., Feldman, W. H., and Pfuetze, K. H.: Treatment of Tuberculosis with Streptomycin, J. A. M. A. 132: 778, 1946.
4. Adcock, J. D., and Hettig, R. A.: Absorption, Distribution, and Excretion of Streptomycin, Arch. Int. Med. 77: 179, 1946.
5. Zintel, H. A., Flippen, H. F., Nichols, A. C., Wiley, M. M., and Rhoads, J. E.: Studies of Streptomycin on Man. I. Absorption, Distribution, Excretion, and Toxicity, Am. J. M. Sc. 210: 421, 1945.
6. Stebbins, R. B., Graessle, O. E., and Robinson, H. J.: Studies on the Absorption and Excretion of Streptomycin in Animals, Proc. Soc. Exper. Biol. & Med. 60: 68, 1945.
7. Steenken, W., Jr., D'Esopo, N. D., and Wolinsky, E.: Excretion of Streptomycin Into Tuberculous Cavities, the Pleural Space, and the Tracheobronchial Tree, Am. Rev. Tuberc. 56: 403, 1947.
8. Romansky, M. J.: A Method for Assaying Streptomycin in Body Fluid, Methods in Medical Research, Vol. I, Chicago, 1948, The Year Book Publishers, Inc., p. 50.

(See discussion on page 55.)

COMPARISON OF RESULTS IN TWO HUNDRED CONSECUTIVE RESECTIONS FOR PULMONARY TUBERCULOSIS

ONE HUNDRED WITHOUT STREPTOMYCIN THERAPY AND ONE HUNDRED WITH STREPTOMYCIN THERAPY

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IN ATTEMPTING to draw a proper comparison between those patients with pulmonary tuberculosis who received streptomycin therapy before and after surgery with those who did not, it soon became apparent that there were many practical difficulties. For example, the cases in which streptomycin was not given were nearly all in an earlier group chronologically. Some extended back to 1941. Thus, many patients were operated upon without the advantage of more recent surgical and anesthetic improvements. This includes the face-down or Overholt position for surgery. Moreover, the first group was not subjected to routine postresection thoracic space reduction (usually thoracoplasty), nor did these patients have the benefit of our more critical present-day preoperative evaluation and greater experience in handling pre- and postoperative problems.

In contradistinction to this nonstreptomycin group, the routine use of streptomycin pre- and postoperatively was started in September, 1946. Thus, all of the streptomycin-treated series are less than two years postoperative. Perhaps some of them will develop complications or flare-ups in the future. On the other hand, some recent cases which are today sputum-positive may soon turn negative.

While the patients in the streptomycin-treated group have been operated upon on the senior author's thoracic surgical services by a more modern surgical and anesthetic technique, at least one-half were actually operated upon by younger and less experienced associates. Almost all of those in the prestreptomyicn group were operated upon by the senior author personally. The newer anesthesia methods and the face-down position have certainly been factors of great benefit in the more recent series but were also utilized in about one-half of the older series. Routine postresection reduction of the size of the thoracic cavity (usually thoracoplasty) was performed in nearly all of the patients in the more recent group, but also in at least three-quarters of those in the older group. It is true that we have had more experience in evaluating cases for surgery, and especially have benefited from the more recently developed pulmonary function tests. The most practical of the present physiologic study methods have been those of Ornstein, Herman, Friedman,

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and Friedlander.[1] We have, therefore, rejected a certain number of poor-risk cases in the second group. An opposing factor, however, is the fact emboldened by better results, have somewhat extended our indications and have at times "pushed our luck" in borderline cases. Also emboldened by the thought that we now had the "advantage" of streptomycin therapy, we have operated upon another type of poor-risk case. Thus, the latter series has included 14 cases of acute pneumonic tuberculosis, 6 cases with contralateral pneumothorax, and 14 cases with homolateral tuberculous empyema, among which 12 cases also had clinical bronchopleural fistulas. These latter were usually subjected to the formidable operation of extrapleural pulmonary resection plus excision of the empyema space.[2]

After consideration of all these difficulties, we nevertheless believe that some interesting and valuable conclusions may be drawn from comparison of the two groups. We were able to follow all of the early cases for at least one year, and the majority of them up to the present time. While there is a group of late untoward developments, most of our important surgical complications occurred early. The chief exception to this is the development of late tuberculous empyema in an unobliterated space remaining after pneumonectomy. Late tuberculous exacerbations which may develop in the same or opposite lung are frequently blamed upon the surgery but may well be due to the natural progress of the disease (which notoriously tends to bilateralization). Perhaps it may be due to an inadequate removal of tuberculous disease already existing at the time of resection. Ornstein[3] has stressed the necessity of bilateral planography in all tuberculous cases subjected to surgery; otherwise, either homolateral or contralateral cavities may be overlooked preoperatively.

Following is a breakdown of the indications for surgery in each group, with the treatment and operative mortality (Tables I and II).

TABLE I. INDICATIONS FOR RESECTION

INDICATIONS	CASES	WITH STREPTOMYCIN		SEGMENTAL	DEAD
		PNEUMONECTOMIES	LOBECTOMIES		
Severe bronchial stenosis	13	12	1	0	2
Associate or residual bronchiectasis	1	0	1	0	0
Ineffective temporary collapse	0	0	0	0	0
Ineffective permanent collapse	16	9	5	2	1
Very large cavity	6	4	2	0	0
Hilar cavity	2	0	2	0	1
Check valve cavity	3	1	1	1	1
Lower lobe cavity	3	0	3	0	1
Progressive cavitary disease (destroyed lungs)	22	20	2	0	2
Acute pneumonic disease	14	12	2	0	5
Tuberculoma	2	0	2	0	0
Bilateral localized	2	0	1	1	0
Elective	2	0	0	2	1
Bronchopleural fistula	12	9	3	0	2
Chronic mixed or simple empyema	2	2	0	0	0
Total	100	69	25	6	16
Surgical deaths	16	11	5	0	

TABLE II. INDICATIONS FOR RESECTION

INDICATIONS	CASES	NONSTREPTOMYCIN		SEGMENTAL	DEAD
		PNEUMONECTOMIES	LOBECTOMIES		
Severe bronchial stenosis	13	12	1	0	4
Associate or residual bronchiectasis	9	4	5	0	0
Ineffective temporary collapse	4	2	2	0	1
Ineffective permanent collapse	28	12	11	5	8
Very large cavity	15	5	7	1	1
Hilar cavity	0	0	0	0	0
Check valve cavity	3	0	2	1	1
Lower lobe cavity	4	1	3	0	1
Progressive cavitary disease (destroyed lungs)	12	10	2	0	9
Acute pneumonic phthisis	2	2	0	0	2
Tuberculoma	2	1	1	0	0
Bilateral localized	0	0	0	0	0
Elective	10	2	6	2	0
Bronchopleural fistula	0	0	0	0	0
Chronic mixed or simple empyema	0	0	0	0	0
Total	102	51	40	9	27
Surgical deaths	27	16	10	1	

DISCUSSION

The foregoing statistical breakdown tends to support certain impressions which have gradually developed. First, it is evident that resection for pulmonary tuberculosis is much safer in our hands since September, 1946 (Table III).

TABLE III. COMMON AND SPECIFIC POSTOPERATIVE COMPLICATIONS

	NONSTREPTOMYCIN		WITH STREPTOMYCIN	
	TOTAL	FATALITIES	TOTAL	FATALITIES
Spreads, contralateral	13	6	1	0
Spreads, homolateral	2	0	0	0
Empyema, pyogenic	4	0	0	0
Empyema, tuberculous	8	5	1	0
Empyema, mixed	1	1	2	0
Chest wall infection and sinus	7	1	2	0
Bronchopleural fistula (early)	7	3	2	2
Bronchopleural fistula (immediately after thoracoplasty)	4	0	1	0
Bronchopleural fistula (late)	3	1	1	0
Total	49	17	10	2

The most gratifying observation is that postoperative contralateral tuberculous spread is almost nonexistent on our service today. The one case of listed contralateral spread was that in which a bronchopleural fistula developed and in which the patient had been operated upon a few weeks previously for mixed infection tuberculous empyema due to acute cavity rupture following a closed pneumonolysis for tension cavity. It seems probable that the spread was related to aspiration of pleural contents and overwhelming infection.

Early postoperative tuberculous empyema did develop in three patients with pulmonary resection in the streptomycin group, one of whom had been subjected to cavitary rupture and gross pleural contamination at operation. This is in contradistinction to thirteen cases of tuberculous empyema in the older group.

Development of bronchopleural fistula was also much less common in the streptomycin-treated group. Of the four cases of bronchopleural fistula in this group, two were in patients originally operated upon for bronchopleural fistula, and one was a case of acute pneumonic phthisis with contralateral disease under pneumothorax collapse. In an attempt to save much needed lung tissue, a multiple segmental resection was performed, although some questionably caseating lung tissue was left behind. This case was obviously a poor choice for any surgery. Another case was a pneumonectomy for destroyed lung. While there was no obvious reason for this man developing a bronchopleural fistula, it appeared a few weeks after thoracoplasty and was preceded by an unexplained fever throughout the surgical period. Perhaps he had a silent empyema of small size all that time.

Of the entire group of specific complications commonly seen after resection for pulmonary tuberculosis and which had occurred 49 times in the nonstreptomycin series, only 10 appeared in the group of streptomycin-treated cases. Whereas these complications caused 17 of the 27 deaths (63 per cent) in the first series, they caused only 2 of the 16 in the second series (15 per cent). Both of these deaths occurred in cases which would not have been considered operable at the time the first series was in progress. They were cases of mixed tuberculous empyema with bronchopleural fistula due to acute cavitary rupture.

The next noteworthy observation is the increased number of cases of extensive lung destruction (22) and acute pneumonic phthisis (14) in the streptomycin group, as compared to 12 of the former and 2 of the latter in the nonstreptomycin group (Table I). *The surgical results were dramatically* different in each series. Thus, of the 14 cases in both classifications in the nonstreptomycin group, 11 patients died (78.5 per cent). This is in line with the experiences of Sweet[1] and others with resection therapy for this type of case. On the other hand, of the 36 cases in the streptomycin-treated series only 7 patients died (19.4 per cent), 5 of these being in the acute pneumonic phthisis classification. *Our overwhelming impression is that this marked reduction in mortality with these very serious cases is practically entirely due to the use of streptomycin.* Reasoning along the lines of Pfuetze and associates[5] we would expect the suppressive effect of streptomycin in these cases of extensive to overwhelming pulmonary infection to produce a temporary reversion of the case to the status of less active and progressive disease. The surgical results should then become comparable to those in the more chronic classifications. Indeed, the mortality of the cases of "destroyed lung" under streptomycin therapy is quite satisfactory (9 per cent). The persistent high mortality (35.7 per cent) in the cases listed as acute pneumonic phthisis is probably due to the fact that the overwhelming infection cannot be as completely suppressed and that they still represent cases of fairly active tuberculosis at the time of surgery. We believe that the mortality would have been much higher in this group had streptomycin not been used. Packard[6] has urged a much longer preoperative period of streptomycin in such cases. However, we must not prolong this therapy to the point of losing the specific suppressive effect before surgery. Streptomycin-fastness of the concerned bacteria may well develop within six weeks.

Respiratory insufficiency, paradoxical breathing, and acute postoperative pulmonary edema were deemed causative of six deaths in the streptomycin-treated group, or 37.4 per cent of all deaths in this series. In the nonstreptomycin group only 2 deaths were listed as due to these causes, or 7.4 per cent of deaths in that series (Table IV and V). We believe that this increase in the later series is a direct reflection of our attempts to extend the indications somewhat in cases of borderline cardiopulmonary functional insufficiency. It can undoubtedly be reduced by a more careful screening of these cases *after* functional studies have been completed. Both Ornstein[3] and Crellin[7] have pointed this out in reviewing our series.

The remaining causes of death in both series are of wide variety and individual rarity. With the exception of a case of tuberculous pericarditis (operative opening of the pericardium) and one of tuberculous meningitis, they had no direct relation to the tuberculous process (unless we consider

TABLE IV. CAUSES OF DEATHS (STREPTOMYCIN GROUP)

Acute pulmonary edema	2
Bronchopleural fistula and mixed empyema	2
Contralateral spontaneous pneumothorax	1
Cardiac cessation on operating table	2
Paradoxical breathing	1
Hemorrhage, laceration of inferior vena cava	1
Respiratory insufficiency	3
Transfusion reaction (hemolysis)	1
Continuous oozing postoperatively	1
Amyloid disease with urema	1
Pulmonary embolism	1
Total	16

TABLE V. CAUSES OF DEATHS (NONSTREPTOMYCIN GROUP)

Postoperative cardiac failure (pulmonary edema)	1
Operative cardiac arrest	1
Tuberculous meningitis	1
Tuberculous pericarditis	1
Uremia due to amyloid disease	1
Acute postoperative anuria	1
3 days postoperative hemorrhage, tourniquet pneumonectomy	1
Chest wall and sinus infection	1
Inability to expectorate secretions postoperatively	1
Respiratory insufficiency	1
Spreads, contralateral	6
Tuberculous empyema	5
Mixed empyema	1
Bronchopleural fistula (early)	3
Bronchopleural fistula (after six months)	1
Uremia due to transfusion reaction	1
Total	27

the causation of amyloid disease). The cases of operative cardiac arrest were essentially due to very poor condition of the patient (2 were cases of acute pneumonic phthisis). There was also one case of reflex cardiac arrest in the older series, successfully treated by massage. In general, these causes of death were such as might be expected in any series of pulmonary resections irrespective of pathology. *While they can probably be diminished by further* improvements in selection, surgical technique, and postoperative care, it is doubtful if they can ever be entirely eliminated. There were eight such deaths in each series.

There has been considerable variation in the amount and duration of streptomycin therapy. However, we have basically given 1 Gm. daily for two weeks preoperatively and for three weeks after operation. In especially acute cases and those with excessive sputum, the dose has frequently been doubled and given for three to four weeks preoperatively and up to eight weeks after the resection. In no case has the daily adult dose been less than 1 Gm. In some individuals, of restricted financial capacity, streptomycin was begun just two to three days preoperatively and continued for an equal period postoperatively (two to three days). In no such instance did we feel that the patient was harmed, but we did limit this group to those with the more conservative surgical indications. We have repeatedly been able to confirm the observation of Ornstein[1] that there is a remarkable reduction in the amount of sputum and diminution in its purulent content during the two weeks preoperative streptomycin regime. While this sputum rarely becomes bacillus-free, the Gaffky count usually drops. It is our impression that these changes in the amount and character of the sputum remarkably reduce the chance of operative flooding of other portions of the bronchial tree with consequent reduction in the tendency to atelectasis and bronchiogenic spread. The relative absence of operative spreads (one case only, 1 per cent) in the streptomycin-treated group, as contrasted to the older group (15 per cent) certainly tends to bear this out. A factor of considerable importance in the prevention of postoperative atelectasis is attention to the *tracheobronchial toilet*. This includes the ordinary mechanisms of air passage evacuation such as encouragement of cough, carbon dioxide inhalation, transnasal transglottic tracheobronchial aspirations, bronchoscopy in the postoperative period, and occasionally tracheotomy for frequent aspiration. We are especially grateful for the help of Dr. J. A. Crellin of Philadelphia,[7] and Dr. Morris Pierson of Wilmington, Del.,[8] who have contributed to the setting up of the program of treatment which has worked so well in these cases.

We have felt that streptomycin therapy markedly reduced the postoperative incidence of tuberculous empyema except in those cases where a clinical bronchopleural fistula develops. This was especially evident in those cases where operative rupture of a caseous area led to gross contamination in the pleural space. Thus in 23 cases of operative gross pleural contamination in the prestreptomycin group, tuberculous empyema resulted in 13 instances (58 per cent). On the other hand in 18 cases in the streptomycin series only 3 empyemas resulted (18 per cent).

The protective effect of streptomycin also was very evident in cases of clinical tuberculous or mixed empyema, with or without bronchopleural fistula, which were treated by resection. While an attempt was usually made to remove the entire empyematous space, it was completely accomplished in only three instances, and pleural contamination occurred in two of those because of operative opening of the empyematous sac. Yet, pleural infection was demonstrable postoperatively in only 3 of the 12 cases (25 per cent). The rarity of chest wall infection and sinus development in these cases was most impressive, occurring in only two instances. One patient, who had had a fairly long (eight weeks) preoperative course of streptomycin, did develop a draining sinus which has existed about six months. She had had a wide bronchial fistula and pleural infection for more than one year preoperatively. At the time of operation, it was necessary to leave a large portion of the empyematous wall on the diaphragm and pericardium.

The occurrence of bronchopleural fistula in the early postoperative period is usually related to a failure of proper bronchial closure, although virulent pleural or mediastinal infection may well lead to sloughing of the suture line. This is probably aggravated by early severe coughing which applies extreme pressure to the suture line. We have observed a number of cases which have maintained a closed bronchus for three to five weeks postresection, then following an obliterative thoracoplasty the patient complained of blood spitting (brownish), and/or of extreme bulging of the softened chest wall. The bronchus apparently opened due to the force of coughing in the absence of the support of the intact costal cage. For such rupture to occur so long after the time of probable secure bronchial healing (fourteen days) suggests that normal healing had not taken place. Overholt[9] has shown that this is frequently due to ulceration in the bronchial stump. Since routine examination of the cut bronchus in resection cases reveals, according to Auerbach,[10] miliary tubercles in about 40 per cent of cases, it is not surprising that ulceration of the bronchial stump may occur. In view of the many favorable reports upon the use of streptomycin in endobronchial tuberculosis, it would seem probable that it should tend to prevent this stump ulceration, or to cause healing once such ulceration has occurred.

It is interesting to note that opening of the bronchus immediately after postresection thoracoplasty occurred in 4 cases in the prestreptomycin series and in one case of the streptomycin series. This latter case was the one of acute pneumonic phthisis with bilateralization in which multiple segmental resection was employed. We believe that the use of a double suture line, one of interrupted end sutures and one proximal mattress row, is of considerable protection against such an occurrence. We prefer stainless steel because of its inertness.

From this appraisal of our entire experience with pulmonary resection for tuberculosis, we have come to the conclusions that the beliefs first voiced upon the use of streptomycin in resection for pulmonary tuberculosis by Glover, Clagett, and Hinshaw[12] are essentially corroborated. Providing a

TABLE VI. BREAKDOWN OF CASES WITH PATIENTS LIVING

Results to date (nonstreptomycin group)		
Total	100	
Surgical deaths	27	
Deaths since operative period	10	
Living	63	
Known negatives (present)	55	(87.3% of living)
Unable to follow up	4	(6.3% of living)
Known positives	4	(6.3% of living)
Residual chest wall drainage	6	(10.5% of living)
Results to date (streptomycin group)		
Total	100	
Surgical deaths	16	
Deaths since operative period	0	
Living	84	
Known negatives	77	*(91.5% of living)*
Unable to follow up	0	
Known positives	2	(2⅓% of living)
Undetermined	5	(Very recent or no sputum determination available)
Residual chest wall drainage	4	(4⅔% of living)

previous course of streptomycin therapy has not rendered the patient bacteria *streptomycin-fast, a definite suppression of the tuberculous process is produced* during the preoperative therapy. The patient's disease then temporarily assumes a more chronic course, so that it can be subjected to surgery with a much greater margin of safety. In the treated group, the incidence of tuberculous operative spreads and flare-ups became practically nil. Infections of the pleura and chest wall were remarkably reduced in spite of the inclusion of 14 cases of empyema (with proved bronchopleural fistula in 12 cases) in the streptomycin-treated group.

The complications which are essentially due to the resection rather than to the tuberculosis were unchanged. While more difficult cases were frequently chosen for surgery in the streptomycin-treated group improvements in surgical technique rendered the nonspecific complications and mortality about the same.

We believe today that the mortality in pulmonary resection for tuberculosis can be set at any figure over 5 per cent, dependent upon the type of case selected for resection, and the choice between radical or conservative management must be left to the judgment of each individual clinic.

We cannot, of course, give an accurate idea of the relative incidence or freedom from late complications in these two series. However, there is nothing in our experience to suggest that the late results after resection surgery are essentially different from the late results in other forms of major surgery for pulmonary tuberculosis (Table VI).

REFERENCES

1. Ornstein, G. G., Herman, M., Friedman, M., and Friedlander, E.: Am. Rev. Tuberc. 53: 306, 1945.
2. Sarot, Irving: Personal Communication.
3. Ornstein, G.: Personal Communication.
4. Sweet, Richard: J. THORACIC SURG. 15: 373-383, 1946.

5. Pfuetze, Karl, Glover, R. P., White, E., and Hinshaw, H. C.: Dis. of Chest 13: 1947.
6. Packard, J. C.: Personal Communication.
7. Crellin, J. A.: Personal Communication.
8. Pierson, Morris: Personal Communication.
9. Overholt, R. H., Langer, L., Szypulski, J. T., and Wilson, N. J.: J. THORACIC SURG. 15: 384-413, 1946.
10. Auerbach, O.: Personal Communication.
11. Davidson, L. R.: Personal Communication.
12. Glover, R. P., Clagett, O. T., and Hinshaw, H. C.: Am. Rev. Tuberc. 55: 1947.
13. Churchill, E. D., and Klopstock, R.: Ann. Surg. 117: 641, 1943.
14. Bailey, C. P.: J. THORACIC SURG. 16: 328, 1947.
15. Bailey, C. P., Tropea, F., Jr., and Rubenstein, L. H.: S. Clin. North America, 1947.
16. Cournand, A., Himmelstein, A., Riley, R. L., and Lester, C. W.: J. THORACIC SURG. 16: 30, 1947.
17. Birath, G., Crafoord, C., and Rudstrom, P.: J. THORACIC SURG. 16: 492, 1947.
18. Rienhoff, W. F., Jr.: J. THORACIC SURG. 8: 254, 1939.
19. Army, Navy, & Veterans Administration: Am. Rev. Tuberc. 56: 485-605, 1947.

(See discussion on page 55.)

AN EVALUATION OF STREPTOMYCIN AS A PROTECTIVE AGENT IN PULMONARY RESECTION FOR TUBERCULOSIS

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THE first attempts to resect pulmonary tissue were made by Gluck,[1, 2] Schmid,[3, 4] Block,[5, 6] Biondi,[7] and Ziino[8] between the years 1881 and 1883. Tuffier[9] wrote of Gluck's and Schmid's extirpation of the lung in an animal and of *an experiment by Biondi in which the lung of an experimental animal* was inoculated with the tubercle bacillus and the resultant disease eradicated by pneumonectomy. Tuffier concluded: "In the first stroke, therefore, ex*perimentation had achieved the end of its domain. All of those who succeeded* these experimenters . . . have only confirmed their conclusions."

We are familiar with Block's first tragic attempt to perform a bilateral, apical resection for tuberculosis in 1881,[10] and with similar unsuccessful attempts by Ruggi[11] and Kroenlein.[12] Tuffier performed what is accepted as the first successful resection for tuberculosis in man in 1893. This was followed by the cases of Lowson in 1893[13] and Doyen in 1895.[14] Many surgeons attempted, successfully and unsuccessfully, to perform resections with varied technics until 1932, when Graham,[15] Lilienthal,[16] Freedlander,[17] and Rienhoff[18] reported their cases. The success of the latter group led to renewed efforts to eradicate tuberculosis by excision of the diseased tissue.

Thornton and Adams,[19] Dolley and Jones,[20] Behrend,[21] and Clagett[22] reviewed the literature up to 1944 and found that less than 90 cases of pulmonary resection for tuberculosis had been reported. We reviewed the American literature up to May, 1948, and found reported 616 cases of resection for pulmonary tuberculosis with a total mortality rate of 26 per cent and an operative mortality rate of 15 per cent in those cases in which the rate could be determined (Table I). The mortality rate for pneumonectomy was slightly more than twice that for lobectomy. Unfortunately, all surgeons have not reported in detail the causes of death nor the complications, such as spreads or exacerbations of tuberculosis, bronchial fistulas and empyemas, which are the main causes of the high mortality and morbidity accompanying these operations.

There was either a spread or an exacerbation of tuberculosis in 26 per cent of 456 cases (Table II). The incidence was higher following lobectomy (31 per cent) than following pneumonectomy 24 per cent). Empyema developed in 50 cases, or approximately 12 per cent of 421 resections (Table III).

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From the Department of Surgery, U. S. Veterans Hospital, Oteen, N. C.: published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or conclusons drawn by the authors.

TABLE I. REVIEW OF AMERICAN LITERATURE OF PULMONARY RESECTIONS 1881-1948, MORTALITY RATE

AUTHORS	TOTAL NO. OF CASES	OVER-ALL NO. OF DEATHS	PER CENT OVER-ALL MORTALITY	NO. POST-OPERATIVE DEATHS 1ST 2 MO.	PER CENT MORTALITY 1ST 2 MO.
Composite of Thornton,[19] Dolley,[20] and Behrend[21]	85	34	40	Figures not obtained	Figures not obtained
Overholt[23]	196	46	24	27	14
Bailey[24, 25]	129	37	29	30	23
Sweet[26]	63	21	33	9	16
Janes[27]	32	6	19	2	6
Clagett[28]	29	4	14	2	7
Strieder[29]	23	4	17	3	13
Carr[30]	18	7	39	6	33
Maier and Klopstock[31]	16	1	6	1	6
Churchill[32]	9	1	11	0	0
Duncan[33]	5	0	0	0	0
Shenstone[34]	2	0	0	0	0
Total	607	161	26	80	15

In 31 of these, the empyema was tuberculous or mixed, while in the remaining 19 the empyema was pyogenic. Bronchial fistulas developed in 6 per cent, and all of these resulted in empyema.

In 1947 Overholt and his associates[23] reported that the operative mortality for both lobectomy and pneumonectomy was then approximately 5 per cent in patients who were considered reasonably good risks, and 43.6 per cent in pa-

TABLE II. REVIEW OF AMERICAN LITERATURE OF PULMONARY RESECTIONS 1934-1948, COMPILATION OF SPREADS AND/OR EXACERBATIONS

AUTHORS	NUMBER OF CASES	NUMBER OF SPREADS AND/OR EXACERBATIONS	PER CENT OF SPREADS AND/OR EXACERBATIONS
Overholt[23]	196	54	28
Bailey[24, 25]	80	15	19
Sweet[26]	63	20	32
Janes[27]	32	5	16
Clagett[28]	29	8	28
Strieder[29]	23	11	48
Maier[31]	16	1	6
Brantigan[35]	9	1	11
Duncan[33]	5	0	0
Churchill[32]	3	2	66
Total	456	117	26

TABLE III. REVIEW OF AMERICAN LITERATURE OF PULMONARY RESECTIONS 1934-1948, COMPILATION OF FISTULAS AND EMPYEMAS

AUTHORS	NUMBER OF CASES	NUMBER OF EMPYEMAS	PER CENT EMPYEMAS DEVELOPED	NO. OF FISTULAS	PER CENT FISTULAS DEVELOPED
Overholt[23]	196	22	11	12	6
Bailey[24, 25]	80	10	13	7	11
Sweet[26]	63	7	11	2	3
Janes[27]	32	6	19	4	13
Clagett[28]	29	3	10	2	7
Maier[31]	16	2	13	0	0
Duncan[33]	5	0	0	0	0
Total	421	50	12	27	6

tients who were very poor risks. Over a period of years Overholt has been able gradually to reduce the mortality rate and the incidence of spreads, bronchial fistulas, and empyemas. After he began to operate with the patient in the prone position, the results improved. His most recent report of results with use of the face-down position and local anesthesia stated that spreads or exacerbations occurred in 14 patients, or 13 per cent. Empyemas occurred in 6 per cent, and fistulas in 2 per cent of operations. Sputum was converted in 60 per cent of 104 patients in the series, while the average rate of sputum conversion reported in the literature is 50 per cent.

Prior to 1947 our experience with resection of the lung for tuberculosis had not been very extensive (Table IV). We had performed 2 pneumonectomies and 9 lobectomies for tuberculosis. Our operative mortality was 18 per cent, and the late mortality 18 per cent. Twenty-seven per cent of the patients developed spreads or exacerbations, and 55 per cent developed fistulas and empyemas. In 6, or 55 per cent, the sputum became negative. Our experience was probably worse than the average and we were not enthusiastic about resecting tuberculous lungs.

In June, 1946, the Veterans Administration Hospital at Oteen, N. C., was invited to participate in a co-operative study to evaluate the action of streptomycin in the treatment of tuberculosis. At first the use of streptomycin was confined to the treatment of chronic draining sinuses and selected cases of pulmonary tuberculosis. Results in this group have been reported by Brock, Parnell, and Moyer.[26, 27]

In January, 1947, this study was expanded to evaluate the prophylactic effect of streptomycin during various surgical procedures for tuberculosis. Shortly after this study was initiated at Oteen, streptomycin became available at the Western North Carolina Sanatorium at Black Mountain, N. C. We wish to report at this time our results of pulmonary resection for tuberculosis with the use of streptomycin at these two institutions.

The Streptomycin Committee established arbitrarily a dosage of 2 Gm. intramuscularly, divided into six doses daily, to be given one week before and two weeks after operation. This method was followed until October, 1947, at which time the dosage was cut to 1 Gm. daily, divided into two doses given at twelve-hour intervals begun one week before and continued for two weeks after operation. The reduction in amount of streptomycin was made because of the serious toxic effects and the development of resistance to the drug noted in the study on pulmonary patients being conducted simultaneously. It was desired, also, to establish the minimum effective dosage of this new therapeutic agent. So far as we can judge, the smaller dosage has been as effective as the larger, and no toxic reactions have resulted from the three weeks' course of treatment with either dosage.

It was felt that the technique of pulmonary resection was fairly well standardized and that the experience of many surgeons demonstrated that the mortality and morbidity rate were almost prohibitive. It was agreed that these reports offered a sufficient background of experience with which to

TABLE IV. OUR RESECTIONS PRIOR TO USE OF STREPTOMYCIN

LOCATION	NO. OF PATIENTS	EARLY DEATHS		LATE DEATHS		EMPYEMAS		FISTULAS		SPREADS AND/OR EXACERBATIONS		POSITIVE SPUTA		NEGATIVE SPUTA		CONTRALATERAL DISEASE PRIOR TO SURGERY	
		NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Oteen	6	1	17	0	0	2	33	2	33	2	33	1	17	4	67	0	0
WNC Sanatorium	5	1	20	2	40	4	80	4	80	1	20	2	40	2	40	1	20
Total	11	2	18	2	18	6	55	6	55	3	27	3	27	6	55	1	9

compare the streptomycin-treated cases. For these reasons it was not deemed practical nor fair to the patients to run a control group of resections without the use of streptomycin. A further condition of the study was that indications for operation should not vary from those in use at the respective clinics before streptomycin was used.

The criteria which we have accepted as indications for resection are as follows:

1. Residual cavity after thoracoplasty. Thirty-eight of the 85 resections, or 45 per cent, were done for this reason. Of these, 35 per cent showed endobronchial disease.
2. Failure of more conservative methods of collapse therapy such as pneumothorax and pneumoperitoneum; 13 cases, or 15 per cent of the total number were in this category. Five of these patients had endobronchial disease; 5 had a hilar or a basal cavity.
3. Tuberculous bronchiectasis. Thirteen operations were done for this reason.
4. Destroyed lung. Pneumonectomy was performed under this indication in 10 cases.
5. As an elective operation in place of thoracoplasty; 7 patients were operated upon for this reason. None had demonstrable endobronchial disease.
6. Severe endobronchial disease with stenosis. Three operations, or 4 per cent of the total number, were performed for this lesion.
7. Tuberculoma; one operation.

In 40 per cent of all resections, a preoperative bronchoscopic examination revealed endobronchial disease.

All of these patients were operated upon under intratracheal anesthesia by the closed circle anesthesia technique introduced by Sword[35] in 1928. Cyclopropane, ethylene, or ether was employed; occasionally curare was administered if the motion of the diaphragm proved troublesome during operation. Throughout the operation the anesthetist kept the tracheobronchial tree free of sputum.

At Oteen all patients were operated upon in the prone or Overholt position; at the State Sanatorium, because of lack of equipment, all operations were done with the patient in the lateral position. Streptomycin was given intramuscularly, beginning one week before and continued for two weeks after operation. It was not instilled into the pleural space. Penicillin was instilled into the pleural space before closure of the pleural cavity and was given parenterally in adequate doses following operation. Undoubtedly, this measure has played an important part in the prevention of pyogenic infection of the wound and the pleura.

All operations, except one in which technical difficulties made the use of a tourniquet necessary, were done by the individual ligation technique. In this patient the bronchi were closed individually and covered with pleura, but later a fistula and empyema developed. In all cases the bronchus was closed with interrupted sutures of fine silk or fine stainless steel wire and covered with a pleural flap, or allowed to retract so that the mediastinal pleura could be sutured over it. The vessels were ligated individually with heavy silk reinforced with a transfixion suture of medium silk.

In all patients treated by pneumonectomy, the chest cavity was drained for forty-eight hours. In the lobectomy cases, drainage was instituted and suction applied until the remaining lobes had re-expanded. Adequate amounts of blood were given during the operation, an average of 2,000 c.c. per patient. Blood was given postoperatively as indicated. All patients were given oxygen as required through an intranasal catheter.

A few patients who developed atelectasis of varying degree were treated promptly by bronchoscopic aspiration.

Seventy-four resections were done on 74 patients between January, 1947, and May 1, 1948, with the use of streptomycin as a prophylactic agent. Of these, 35 were lobectomies and 39 pneumonectomies. One of the 35 lobectomy patients (Table V) died from hemorrhage shortly after operation, a mortality rate of 2.9 per cent. There were no late deaths, and there are no patients who are not doing well at present. One patient developed a fistula with empyema and he is being treated by thoracentesis combined with thoracoplasty. A spread of the disease occurred in one patient, an unco-operative man, who developed a small contralateral area of pneumonitis six weeks after operation. This cleared in one month with streptomycin therapy and the sputum remained negative. One patient developed a progression of the disease sixteen months after surgery and was readmitted to the hospital. Another patient developed tuberculous meningitis about five weeks after lobectomy, and has apparently been cured by the administration of streptomycin. In 92 per cent of the 35 patients the sputum became converted. Contralateral disease was present in 34 per cent, but was considered quiescent at the time of operation. Our immediate results are most gratifying, but we realize that as time goes on, there will probably be reactivation of the disease in some of the patients.

Of the 39 pneumonectomy patients, 5 died, an operative mortality of 13 per cent (Table VI). One patient died of uncontrollable hemorrhage on the operating table; one died several days after operation from the effects of cerebral anoxia caused by cardiac arrest, the result of severe hemorrhage on the table. One died of right ventricular failure seventeen days postoperative. One died of a contralateral spread of the disease. It is interesting to note that this patient had been given 2 Gm. of streptomycin daily for seven months before admission for operation. Undoubtedly the organisms had become resistant to streptomycin, and the patient lost the protective value of the drug. A fifth death occurred in a diabetic patient ten days after operation, immediately following an attempted thoracentesis. A post-mortem examination failed to reveal any satisfactory explanation for death.

Three patients, or 8 per cent, developed fistulas and empyemas. These were treated by thoracotomy and thoracoplasty. In 1 a tuberculous wound infection developed after thoracoplasty. In 2, or 5 per cent, spreads or ex-

TABLE V. OUR LOBECTOMY RESULTS USING STREPTOMYCIN

LOCATION	NO. OF PA-TIENTS	EARLY DEATHS		LATE DEATHS		EMPYEMAS		FISTULAS		SPREADS AND/OR EXACERBA-TIONS		POSITIVE SPUTA		NEGATIVE SPUTA		CONTRALATER-AL DISEASE PRIOR TO SURGERY	
		NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Oteen	33	1	3	0	0	1	3	1	3	1	3	2	6	30	90	11	33
W.N.C. Sanatorium	2	0	0	0	0	0	0	0	0	0	0	0	0	2	100	1	50
Total	35	1	2.9	0	0	1	2.9	1	2.9	1	2.9	2	5.7	32	92	12	34

TABLE VI. OUR PNEUMONECTOMY RESULTS USING STREPTOMYCIN

LOCATION	NO. OF PA-TIENTS	EARLY DEATHS		LATE DEATHS		EMPYEMAS		FISTULAS		SPREADS AND/OR EX-ACERBATIONS		POSITIVE SPUTA		NEGATIVE SPUTA		CONTRALATER-AL DISEASE PRIOR TO SURGERY	
		NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Oteen	27	2	7	0	0	3	11	3	11	0	0	1	4	24	89	6	22
W.N.C. Sanatorium	12	3	25	0	0	0	0	0	0	2	17	2	17	8	67	7	58
Total	39	5	13	0	0	3	8	3	8	2	5	3	8	32	82	13	33

acerbations occurred. One of these patients died, as reported previously; the other recovered with the continued use of streptomycin.

In 32, or 82 per cent of the pneumonectomy group, the sputum became negative. This is rather remarkable, inasmuch as in 33 per cent contralateral disease was present, and in 17 per cent it was considered to be active at the time of operation. There have been no late spreads or deaths in this group. Here again we realize that eventually some of these patients will die of tuberculosis.

The 74 cases of resection of the lung with streptomycin are listed in Table VII. The operative mortality is 8.1 per cent. There have been no late deaths to date. In 5 per cent empyemas developed and were considered to be the result of fistulas. These were assumed to be tuberculous, even though the organisms could not be demonstrated in all instances. In 5 per cent bronchial fistulas developed, probably from failure to maintain a tight closure of the bronchus. This fault in technique should occur with less frequency in the future. Spreads followed 4 per cent of the operations. There have been no deep tuberculous wound infections and only a few minor wound infections following resection, and no late spreads or empyemas to date, but there has been progression of disease in one patient sixteen months after operation.

In our cases the mortality rate has been reduced from 36 per cent to 8.1 per cent; the rate of spreads from 27 per cent to 4 per cent; the rate of fistulas and empyemas from 55 per cent to 5 per cent; and the rate of sputum conversion has risen from 58 per cent to 87 per cent. Ninety-two per cent of the living patients have a negative sputum.

We feel that streptomycin has been the major factor in lowering the mortality and morbidity rate in our experience. We frankly admit, however, that at the time we began the use of streptomycin we had not had a large experience with the operation of pulmonary resection, particularly in tuberculosis. We had not mastered the individual ligation technique. It is our opinion that improvement in operative technique and skill, improved methods of anesthesia, the use of adequate amounts of blood, improvement in preoperative and postoperative care, and the meticulous attention to details throughout the entire period of treatment have contributed materially to the improvement in results.

We believe that adoption of the Overholt position has been a definite factor in the reduction of spreads. In patients operated upon at the Western North Carolina Sanatorium where the lateral position is used, there was an incidence of 14 per cent of spreads. At Oteen, where the Overhold position is used, the incidence of spreads was 1.6 per cent.

The fact that no patient developed serious wound infection and none developed empyema, except in cases with bronchial fistulas, proves to us that protection against gram-positive organisms is afforded by penicillin and against gram-negative organisms and the tubercle bacillus by streptomycin. In 25 per cent of the cases, particularly in cases of resection after thoracoplasty, gross contamination of the pleural cavity has occurred due to rupture

TABLE VII. OUR TOTAL RESECTION RESULTS USING STREPTOMYCIN

LOCATION	NO. OF PATIENTS	EARLY *DEATHS*		LATE *DEATHS*		EMPYEMAS		FISTULAS		SPREADS AND/OR EXACERBATIONS		POSITIVE SPUTA		NEGATIVE SPUTA		CONTRALATERAL DISEASE PRIOR TO SURGERY	
		NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Oteen	60	3	5	0	0	1	7	1	7	1	1.5	3	5	54	90	17	35
W.N.C. Sanatorium	14	3	21	0	0	0	0	0	0	2	14	2	14	10	72	8	57
Total	74	6	8.1	0	0	4	5	4	5	3	4	5	7	64	87	25	34

of the cavity. We have not been able consistently to free these densely adherent lungs without a rupture into the cavity. Yet in no instance has this accident resulted in empyema or wound infection.

We are of the opinion that streptomycin is a suppressive or bacteriostatic agent of proved value against the tubercle bacillus. It is not a cure for tuberculosis. In certain types of cases, however, it has proved to be of inestimable value in controlling the disease. It is too early for any one to attempt to assess its value in the treatment of tuberculosis. This cannot be done until several years have elapsed. From our clinical experience we feel that its chief place in the treatment of tuberculosis is as an adjunct to establish collapse procedures. Streptomycin has made it possible for us to perform a lobectomy or a pneumonectomy for tuberculosis with a low morbidity and mortality rate and with excellent early results.

If late results after pulmonary resection prove to be as gratifying as those after thoracoplasty, we are confident that the indications for pulmonary resection will be greatly extended.

REFERENCES

1. Gluck, T.: Experimenteller Beitrag zur Frage der Lungen-exstirpation, Berl. klin. Wchnschr. 18: 645-648, 1881.
2. Gluck, T.: Nochmals die Lungenexstirpation, Deutsche med. Wchnschr. 7: 667, 1881.
3. Schmid, Hans: Experimentelle Studien über partielle Lungenresektion, Berl. klin. Wchnschr. 18: 757-759, 1881.
4. Schmid, Hans: Lecture, read at the 54th Congress of Natural Scientists, Salzburg, September, 1881. Later read before the Berlin Medical Society.[3]
5. Block: Lecture, De la résection du poumon et de ses indications avec présentation d'animaux qui ont subi cette opération, Gaz. méd. de Strasb. 41: 142-143, 1882; also in J. de méd. de Paris 3: 514-515, 1882.
6. Block: Experimentelles zur Lungenresektion, Deutsche med. Wchnschr. 7: 634-635, 1881.
7. Biondi: Gior. internaz. d. sc. med. 4: 759, 1882; 5: 248, 417, 1883; 5: 736, 1884.
8. Ziino: Sull'estirpazione parziale del polmone, Gior. internaz. d. sc. med. 4: 695-698, 1882.
9. Tuffier, T.: Chirurgie du Poumon, en particulier dans les cavernes tuberculeuses et la gangrène pulmonaire, Paris, 1897, Masson & Cie.
10. Walton, G. L.: Pneumonectomy, Boston M. & S. J. 108: 261, 1883.
11. Paget, Stephen: Surgery of the Chest (Bristol), London, 1896, John Wright & Sons, Ltd., pp. 326-330.
12. Kroenlein: Quoted by Paget.[11]
13. Lowson, D.: A Case of Pneumonectomy, Brit. M. J. 1: 1152, 1893.
14. Doyen, E.: Chirurgie du poumon, Congrès de Chirurgie 9: 104-106, 1895.
15. Graham, E. A.: Comments on pneumonectomy in discussion of paper by Lilienthal, H. J., in J. THORACIC SURG. 2: 600, 1933.
16. Lilienthal, H.: Pneumonectomy for Sarcoma in a Tuberculous Patient, J. THORACIC SURG. 2: 600, 1933.
17. Freedlander, S. O.: Lobectomy in Pulmonary Tuberculosis, J. THORACIC SURG. 12: 132, 1935.
18. Rienhoff, W. F., Jr.: The Surgical Technic of Total Pneumonectomy, Arch. Surg. 32: 218, 1936.
19. Thornton, T. F., Jr., and Adams, W. E.: The Resection of Lung Tissue for Pulmonary Tuberculosis, Surg., Gynec. & Obst. (Internat. Abstr. Surg.) 75: 312, 1942.
20. Dolley, F. S., and Jones, J. C.: Experiences With Lobectomy and Pneumonectomy in Pulmonary Tuberculosis, J. THORACIC SURG. 10: 102, 1940.
21. Behrend, M.: Total Pneumonectomy for Pulmonary Tuberculosis, J. THORACIC SURG. 12: 484-494, 1943.
22. Clagett, O. T., and Luckey, C. A.: Lobectomy in Pulmonary Tuberculosis, Proc. Staff Meet., Mayo Clin. 19: 68-72, 1944.
23. Overholt, R., Wilson, N. J., Szypulski, J. T., and Langer, L.: Pulmonary Resection in the Treatment of Pulmonary Tuberculosis, Am. Rev. Tuberc. 55: 198-222, 1947.

24. Bailey, C. P.: Lung Resection for Pulmonary Tuberculosis, J. THORACIC SURG. 16: 328-342, 1947.
25. Bailey, C. P., Tropea, F., Jr., and Rubenstein, L.: Recent Advances in Pulmonary Surgery, S. Clin. North America 27: 1373-1405, 1947.
26. Sweet, R. H.: Lobectomy and Pneumonectomy in the Treatment of Pulmonary Tuberculosis, J. THORACIC SURG. 15: 373-383, 1946.
27. Janes, R. M.: Total and Partial Pneumonectomy in the Treatment of Pulmonary Tuberculosis, J. THORACIC SURG. 14: 3-19, 1945.
28. Clagett, O. T., and Seybold, W. D.: Resection in Pulmonary Tuberculosis, Proc. Staff Meet., Mayo Clin. 23: 81-89, 1948.
29. Strieder, J. W.: Discussion at end of article by Overholt, R. H., and others: Pulmonary Resection in the Treatment of Tuberculosis—Present-Day Technique and Results, J. THORACIC SURG. 15: 413, 1946.
30. Carr, D., and Harter, J. S.: Lobectomy and Pneumonectomy in Pulmonary Tuberculosis, Dis. of Chest 12: 387-393, 1946.
31. Maier, H. C., and Klopstock, R.: Lobectomy for Pulmonary Tuberculosis, J. THORACIC SURG. 14: 20, 1945.
32. Churchill, E. D., and Klopstock, R.: Lobectomy for Pulmonary Tuberculosis, Ann. Surg. 117: 641-669, 1943.
33. Duncan, R. D., and Carpenter, W. W.: Unilobar Tuberculosis Treated by Lobectomy, Dis. of Chest 13: 636-651, 1947.
34. Shenstone, N. S.: Experiences With Total Pneumonectomy, J. THORACIC SURG. 11: 405-413, 1942.
35. Brantigan, O. C.: Resection of Lung, Arch. Surg. 51: 147-153, 1945.
36. Brock, B. L.: Tuberculous Sinuses, J. A. M. A. 135: 147-149, 1947.
37. Parnall, C., Jr., Brock, B. L., and Moyer, R. E.: Streptomycin in the Treatment of Pulmonary Tuberculosis. A Therapeutic Review of Twenty-Three Patients, Am. Rev. Tuberc. 56: *565-578*, 1947.
38. Sword, B. C.: The Closed Circle Method of Administration of Gas Anesthesia, Anesth. & Analg. 9: 198-202, 1930.

DISCUSSION ON "STREPTOMYCIN AS AN ADJUNCT IN SURGICAL TREATMENT OF PULMONARY TUBERCULOSIS" BY DR. DANIEL A. MULVIHILL, DR. LAURENCE MISCALL, DR. ROBERT KLOPSTOCK, AND DR. JOSEPH BITSACK;* "THE ROLE OF STREPTOMYCIN IN THE SURGERY OF PULMONARY TUBERCULOSIS" BY DR. PAUL T. CHAPMAN, DR. E. J. O'BRIEN, DR. PAUL V. O'ROURKE, AND DR. BRUCE DOUGLAS;† "EXPERIMENTAL AND CLINICAL STUDIES OF THE ROLE OF STREPTOMYCIN IN THE PLEURAL CAVITY" BY DR. EDWARD J. BEATTIE, JR., DR. BRIAN BLADES, AND DR. CHARLES HORTON;‡ "COMPARISON OF RESULTS IN TWO HUNDRED CONSECUTIVE RESECTIONS FOR PULMONARY TUBERCULOSIS" BY DR. CHARLES P. BAILEY, DR. ROBERT P. GLOVER, AND DR. THOMAS J. E. O'NEILL;§ AND "AN EVALUATION OF STREPTOMYCIN AS A PROTECTIVE AGENT IN PULMONARY RESECTION FOR TUBERCULOSIS" BY DR. JULIAN A. MOORE, DR. JAMES D. MURPHY, AND DR. PARKER D. ELROD.

DR. RICHARD H. SWEET, Boston.—I would like to bring forth at least one dissenting voice about something that has been mentioned several times, namely, the use of the face-down position, because as I glanced hastily at Dr. Moore's slides it looked to me as though my results—although it was of course a much smaller series—were not very much different from those of Dr. Overholt and I have always used the standard position. I would like to tell you a story which I believe is pertinent. About two years ago Dr. John Alexander came to Boston to visit both Dr. Overholt and me. He spent one morning watching Dr. Overholt use the face-down position, and then came down and had luncheon with us at Massachusetts General Hospital. He said that the face-down position had been used in sixty-nine cases with only four cases of postoperative spread of the disease. Dr. Henry Beecher, who was present, said, "That is of great interest, because some years ago we pub-

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*See page 1 for article by Mulvihill, Miscall, Klopstock, and Bitsack.
†See page 15 for article by Chapman, O'Brien, O'Rourke, and Douglas.
‡See page 25 for article by Beattie, Jr., Blades, and Horton.
§See page 36 for article by Bailey, Glover, and O'Neill.

lished the results on a series of 149 cases, with eight so-called spreads to the other side.'' Not being much of a mathematician, it seemed to me that the percentages were essentially the same.

It seems obvious from listening to these excellent papers today, that streptomycin is a great help in getting patients through the operation, but I wonder just where its place lies in the subsequent course. Therefore, I wondered if those of you who heard the report two years ago based upon the nonstreptomycin series would be interested to know what has happened to that small group. At that time out of the lobectomy group of 27 cases we had 13 patients who were perfectly well so far as we could tell. In the subsequent years 6 have remained well continuously; 7, however, developed reactivation at some time. Two of those were treated with streptomycin and apparently were restored to a comparatively normal state. Twelve of the original 14 are well today. Of the 17 patients in the original pneumonectomy group reported as well 2 years ago, 14 are still well. That is, without streptomycin.

DR. HERBERT C. MAIER, New York.—There are two points that I should like to discuss. First, in relation to streptomycin and pleural absorption. I think it is important to bear in mind the degree of vascularity of the pleura, as well as the extent of pleural thickening or scarring in interpreting absorption studies. From the pathology as described in the cases studied, it would seem that considerable vascularity of the pleura was present. I wonder, therefore, if the pleura is thickened and relatively avascular, whether the results of similar studies would not show quite a different absorption rate.

The other point that I should like to discuss is the importance of very careful maintenance of the cardiorespiratory physiology at the optimum level during operation and in the early postoperative period after pulmonary resection. In our experience, deaths primarily from cardiorespiratory dysfunction have been less than 1 per cent, irrespective of the type of lesion for which the resection was performed. In the early cases of our series for tuberculosis, spread of the disease was the chief difficulty. During the last two years I have had one postoperative death in those patients who had pulmonary resection for tuberculosis. I think that when pneumonectomy is done following thoracoplasty a very careful adjustment of the intrapleural pressure and position of the mediastinum is particularly important because of the small space that remains. A slight increase in the amount of air trapped in that space may lead to what is called cardiorespiratory dysfunction, but which actually is primarily a disturbance due to mechanical factors. I think that more careful attention postoperatively to the position of the mediastinum as well as being certain that the patient is never anoxic during the operative procedure will reduce morbidity and mortality. I wonder whether studies have been done on the face-down position on the operating table to determine whether any anoxia occurs, because we must keep our patients well oxygenated as well as avoid spread of secretion to the other side. I think such factors may account for some of the differences of opinion and differences in results.

COL. J. H. FORSEE, Denver.—In a rather extensive experience in the use of streptomycin at Fitzsimons General Hospital, and with adequate quantities of this drug available, we have come to define the indications for its use essentially as follows: (1) As a selective measure in which it was believed that collapse therapy would not be necessary to arrest the disease; this has included a very small percentage of patients. (2) To improve operability or to convert an unsatisfactory operative risk in need of surgery into a satisfactory risk. (3) As Dr. O'Brien said, as a prophylactic. We have used streptomycin preoperatively, during operation, and after operation, in all patients coming to thoracoplasty during the past eighteen months. Prophylactically it has been, we believe, of particular value in those patients with large cavities who were otherwise good chronic risks, but in whom the danger of spread of the disease has been considerable. We think the spread of the disease has been decreased by the use of streptomycin. In fact, we have encountered spread of the disease in only one patient among a consecutive series of 78 subjected to thoracoplasty, in whom 232 operations were performed. (4) We have used it for the relief of certain distressing symptoms, such as tuberculous cystitis or tuberculous laryngitis, in chronic far-advanced diseases.

Those patients whom we have felt we have converted from an unsatisfactory risk into a satisfactory one, and in whom we have carried out thoracoplasty, constitute approximately 23 per cent in a total of 78 patients, treated by thoracoplasty, with the use of streptomycin. A few illustrative cases in the latter group will be presented.

CASE 1.—A 29-year-old Negro soldier was hospitalized May 15, 1947, because of a temperature of 102° F. and a mildly productive cough. He was transferred to Fitzsimons General Hospital May 31, 1947, at which time sputum was positive for tuberculosis and Kahn reaction was positive. Chest roentgenogram revealed an exudative infiltration throughout the right lung with large (6 cm.) and smaller cavitation in the right upper lobe and evidence of an extension in the left lower and right lower lung fields. Streptomycin, 2 Gm. daily, was given from June 13 to October 14. In November a tuberculous laryngitis and an ulcerative endobronchial tuberculosis of the right upper lobe orifice was diagnosed. In November the patient was afebrile, sedimentation rate was 25/60, and the exudative infiltration bilaterally had cleared considerably but the upper lobe cavity on the right remained. On Dec. 4, 1947, streptomycin therapy, 1 Gm. daily, was again started. A seven-rib thoracoplasty on the right was carried out between Dec. 18, 1947, and Jan. 30, 1948. Streptomycin was discontinued March 5, 1948, after he had received 332 Gm. over a period of 209 days. The sputum production is now nil and negative on smear and culture. X-ray examination of the chest does not reveal evidence of cavitation. Within eight months from the time of onset of illness, thoracoplasty had been completed.

CASE 2.—A 20-year-old Negro soldier was hospitalized Nov. 10, 1945, because of chest pain and cough. X-ray examination of the chest revealed a shadow of infiltration in the right mid-lung field and sputum was positive for acid-fast bacilli. On Dec. 11, 1945, he suffered a spontaneous pneumothorax on the right, associated with a temperature of 104° F. He gradually improved and was admitted to Fitzsimons General Hospital March 31, 1946. At this time he had lost thirty pounds in weight, was dyspneic to a severe degree, and daily temperature averaged 102° F. The patient was placed on streptomycin, 2 Gm. daily, from June 18 to Oct. 18, 1946. By January, 1947, there had been considerable clearing of the lesions but a cavity remained in the right upper lobe. The patient had received 216 Gm. of streptomycin, 2 Gm. daily, and ten days later a first stage thoracoplasty was carried out. A four-stage ten-rib thoracoplasty was completed March 7, 1947, and streptomycin was discontinued April 1, 1947. He was given 152 Gm. of streptomycin in the second course and a total dosage of 368 Gm. A follow-up letter from Veterans Administration stated sputum examination and gastric washings for tubercle bacilli have been repeatedly negative, general condition is good, and the clinical course symptom-free. He had been a severe disciplinary problem and was discharged from the VA hospital Jan. 28, 1948. Sixteen months elapsed from the onset of the disease until the completion of thoracoplasty, and he was discharged from the hospital ten months after thoracoplasty.

CASE 3.—A 25-year-old white soldier was well until April, 1947, when he had an acute onset of fever, chills, cough, night sweats, and malaise. A roentgenogram of the chest revealed an exudative infiltration throughout the left lung with cavitation of the left upper lobe, and the sputum was positive for acid-fast bacilli. He was admitted to Fitzsimons General Hospital June 22, 1947, at which time he was toxic, with daily temperatures of 100 to 101° F., and expectoration of ¼ cupful of sputum daily. On July 7, 1947, he was started on streptomycin, 2 Gm. daily. After four months of such therapy there had been rather marked resolution of the exudative element as noted on roentgenograms, temperature was normal, and sputum production had decreased to 10 c.c. per day. On November 19 he was started on a second course of streptomycin prior to thoracoplasty. Between Nov. 24, 1947, and Jan. 26, 1948, a four-stage eight-rib thoracoplasty had been performed. Streptomycin was discontinued after 228 days of therapy and a total dosage of 456 Gm. The postoperative course after each operation was uneventful and in April, 1948, the sputum was negative with no evidence of cavitation noted on x-ray examination. From the time of onset of illness to completion of thoracoplasty, nine months had elapsed.

We believe that streptomycin has its best use in preparing patients for thoracoplasty. We believe, as Dr. Sweet has indicated, that lobectomy and pneumonectomy are very important, but we would like to reserve pulmonary resection, in general, for use in cases in which the cavities have failed to close after thoracoplasty.

DR. EDWIN J. GRACE, Brooklyn.—Fleming and Florey at the outset of their vital contributions to the clinical use of penicillin brought out one very important fact, and it is a matter of great regret that many Americans have forgotten this fundamental principle, namely, direct topical therapy. Anything that can enhance the efficiency of topical treatment is a very significant adjunct to antibiotic therapy. Enough experience has been gained to show that the development of resistant bacterial strains is today a very formidable clinical problem. (Slide.) The experimental evidence noted here shows how this dangerous phenomenon of bacterial resistance may be prevented. The bacteriologic phase of our work on the prevention of antibiotic-resistant organisms was done by my colleague, Dr. Vernon Bryson.

If a broth culture of *Staphylococcus aureus* is inoculated with approximately 100,000 cells per cubic centimeter, the number is found at the end of six hours to be 27,000,000 per cubic centimeter, and after a twenty-four hour interval of incubation the final count is approximately 150,000,000. When an equivalent number of cells is grown in aerosol O.T. (*dioctyl ester of sodium sulfosuccinate*), 1:25,000, the number drops below the inoculum size but eventually at twenty-four hours a titer of 13,000,000 organisms per cubic centimeter is found. When growth is in the presence of .02 units per cubic centimeter of penicillin the twenty-four hour viable count is 83,000,000 bacteria per cubic centimeter, most of which can be shown to be penicillin-resistant.

Now a most interesting and clinically significant observation is made when we combine the detergent (aerosol O.T., 1:25,000) and penicillin, .02 units per cubic centimeter. The inoculum of 100,000 cells now falls to 690 per cubic centimeter in six hours and at twenty-four hours no viable cells remain.

This combination of penicillin and the detergent in which we obtain such a high degree of efficiency in the destruction of pathogens is referred to as synergism. The process of bacterial destruction is beyond the additative effect of the two therapeutic agents. We believe that in the application of basic genetic principles involved in the origin of bacterial resistance we may substantially diminish the frequency of clinical problems arising as a result of drug fastness in microorganisms.

In some of the papers presented this morning the speakers refer to patients returning for follow-up after initially good results. What really may be happening is the initial destruction of drug-sensitive organisms as a result of selective elimination by the antibiotic. The patient is then left with the clinically refractory ''resistant strains.'' (Slides.) As the slide demonstrates, when we combine the antibiotic and the detergent we destroy all organisms. Although this experiment was run for twenty-four hours from other data we believe all bacteria were destroyed in between six to twelve hours. With topical antibiotic therapy the clinical question of penetration of tissue is vital in order to effect good topical therapy. Consequently, we have on this second slide a demonstration of efficiency of the detergent in penetrating the femur of a rabbit.

As a control, .3 c.c. of a 1 per cent fast green in saline is injected into the lower end of the bone. The penetration is very limited. However, if this same quantity of dye is dissolved in a detergent, 1:1000 aerosol O.T., and injected in the same manner, the femur is more effectively penetrated, perhaps in part because of the lipophilic properties of the wetting agent. Using this principle clinically in many otherwise hopeless cases of suppurative diseases of the lung including pulmonary tuberculosis, we have effected a cure by the very conservative techniques of topical antibiotic therapy.

The added experimental and clinical evidence we have acquired following a discussion of a paper on suppurative diseases of the lung at the St. Louis meeting, and from the papers read this morning on the use of streptomycin alone, either locally or parenterally, strongly convinces me that antibiotics with detergents topically, or as an aerosol mist, most certainly should be considered the method of choice before any form of surgical intervention.

We have never exceeded 50 to 60 Gm. of streptomycin in these cases and consequently had no permanent eighth nerve damage. Our experience in thoracic infections now exceeds fifty cases.

Our profession should realize that with the advent of antibiotic therapy a new era of medicine has dawned. All treatment for infectious diseases, therefore, should be promptly re-evaluated in strict accordance with the original concept of topical therapy.

DR. LOUIS R. DAVIDSON, New York.—My remarks will be confined to a group of patients operated upon at Sea View Hospital during the year 1947. These patients received streptomycin both preoperatively and postoperatively. Unfortunately, I am not in a position to compare a similar series of cases in which streptomycin was not given during the same period. Seventy-six patients had major surgery. There were 59 excisional cases; 44 pneumonectomies, 13 lobectomies, and 2 lobectomies with segmental resection. Of these 59 cases, 51 patients underwent postexcisional thoracoplasty. Fifteen patients underwent thoracoplasty procedures in stages; 1 patient had a thoracoplasty in stages with a Monaldi intubation. Finally, 1 patient had a revision of a Schede operation. Streptomycin was usually administered for a period of two to three weeks prior to surgery. (1) Postexcisional thoracoplasty patients, therefore, received the drug for three months. (2) Those patients having a conventional stage thoracoplasty received the drug for a period of one and one-half months. (3) Those patients who underwent a muscle splitting thoracoplasty received the drug for two months.

Penicillin.—All patients in this series received penicillin. The drug is usually given two to three days preoperatively and was continued until the temperature returned to normal.

Resistance.—Unfortunately, during the year 1947, no studies of the resistance of the tubercle bacillus were made. Most reports indicate that resistance to streptomycin occurs as early as the thirtieth day. Most of our patients received the major portion of their surgery during this period when the organism was sensitive to streptomycin.

Effects on Sputum.—It was noted that 35 patients had a reduction in both cough and the amount of sputum. In addition, there seemed to be a thickening of the sputum.

Effect on Sinuses.—Streptomycin was used in only two cases. Healing occurred in one month in both. No conclusions could be drawn; however, it will be interesting to follow these cases and note if the wounds remain intact.

Effects on Wounds.—These 76 patients underwent 165 operative procedures; wound complications were encountered in 14 cases. The tubercle bacillus was found on smear or culture in 7 cases. One must recognize that antibiotics have their limitations. It may not be amiss at this point to indicate that intelligent surgical technique is still necessary.

Toxicity.—The reactions noted were transient and were not of such a nature that the drug had to be discontinued; the most frequently encountered reaction was vertigo. Twenty-four patients revealed some reaction. As a rule the vertigo disappeared even though the therapy was continued. In a few cases the vertigo persisted and, obviously, the streptomycin was discontinued. Some of the patients related that relief was obtained by the use of Benadryl. This was not definitely controlled. As a result, therefore, no accurate figures can be advanced. Tinnitus occurred in 6 cases; dermatoses appeared in 7 cases; pruritis in 2 cases—itching was relieved by the administration of Benadryl; nausea and vomiting occurred in 3 cases; transient headaches were manifest in 3 cases. Three patients had reactions sufficiently severe to require discontinuance of the drug.

Postoperative Spread.—Because of varying criteria, it was finally decided to include in this group only cases in which the x-ray findings persisted beyond the immediate postoperative period. Five patients had a postoperative spread. Four of them, however, had negative sputum. In cases of mixed infection tuberculous empyema there has been performed at Sea View Hospital 15 cases of complete pleurectomy and pneumonectomy. It seems to us that streptomycin in these cases plays a spectacular and convincing role. This antibiotic, it must be stressed, is an adjunct only. It still must face the test of time.

DR. N. J. WILSON, Boston.—I should like to present the figures from Dr. Overholt's Clinic for 1947 for the purpose of emphasizing some of the points brought out in the papers.

It seems that streptomycin without any question is a very valuable antibiotic and has made surgery upon the tuberculous patient, especially resection, much safer. We now use streptomycin routinely in both the pre- and postoperative periods in pulmonary resection. Just which patients should receive streptomycin for other procedures is not absolutely clear to us as yet. For instance, in the thoracoplasty series we have used it only in preparing the substandard risks and have done the standard risks without streptomycin.

In 1947, there were 48 pulmonary resections performed, 39 pneumonectomies, and 9 lobectomies. One contralateral spread and one bronchial stump ulcer in the pneumonectomy series and one contralateral spread in the lobectomy series have been the only tuberculous complications in this group. Only one patient died of tuberculous infection. This represents a definite improvement as compared with previous years, in spite of the fact that most of these patients had inadequate streptomycin according to present concepts. These statistics gain significance when tuberculous infection as a cause of death following resection prior to 1947 is analyzed as follows:

In the entire series of 276 resections performed between 1934 and Jan. 1, 1948, there have been 43 infectious deaths including postoperative and late; 17 occurred postoperatively, and 26 late. The significant thing from the standpoint of streptomycin is that all these deaths except seven have been related to a postoperative complication. In other words, only 7 patients have died of progression of old disease. If streptomycin can reduce these postoperative complications, which it seems to do, then the future of these people seems to be very much improved.

DR. JEROME R. HEAD, Chicago.—Two factors have limited the use of streptomycin and prevented an unbiased estimation of its value. These are the unknown factor of complications and the high cost of the drug. In most public institutions lack of funds has made it impossible to supply the drug for every patient, and fear of complications has demanded caution in its use. In order, therefore, to discourage the general demand for it, it has been necessary to exaggerate its dangers and to maintain that it was of value only in particular types of cases. In most larger institutions streptomycin boards have been established to observe its effects and to choose the cases in which it is to be used. One cannot escape the feeling that the conclusions reached by these boards as to indications, dosage, and interval between doses have been seriously influenced by the monetary factor. Very often the members of the boards, even without a basis of experience, became astoundingly adept in telling what case streptomycin would help and what case it would not help, and also in telling from the roentgenogram precisely what type of lesion each shadow represented.

I have never been able to do either of these things. I felt sure, and am still convinced, that with so new a drug and so complicated a disease, a priori judgments are unjustified. One is warranted in saying that streptomycin will or will not benefit any certain case only after he has tried it on this particular case and has determined by experience that it has helped or has not helped.

For the past year we have used streptomycin in every case. The results have been generally good and generally unpredictable. Whereas over past years in our sanatorium we have had an average of 25 deaths a year, in 1947 there were only 9 deaths, and in the first six months of 1948 there has been but 1 death.

Dr. O'Brien said that streptomycin has revolutionized the surgical treatment of tuberculosis. It has done the same thing for the medical management. We should all realize that no one of us any longer knows anything about the amount of rest that is needed or about the indications for collapse. All of the old formulas and equations which we have developed so laboriously from experience have been made valueless because there has been injected into them this unknown factor. We do not know to what extent we can shorten the period of bed rest or in what cases we can dispense with collapse. We must start over again and build new formulas containing this at present unknown factor. For a certain type of case the old formula was: Six months bed rest plus four years pneumothorax = cure. Today that formula is: ? months bed rest plus ? (? years pneumothorax) plus streptomycin = cure. It will take some time to become reoriented.

DR. CAMERON HAIGHT, Ann Arbor.—The indications for treatment in pulmonary tuberculosis are changing as a result of the use of streptomycin. In view of the limited time that streptomycin has been available, it is somewhat difficult at present to crystallize the absolute indications for some of the types of treatment. This situation pertains to pulmonary resection, about which I would like to make a few remarks concerning indications and immediate results in patients who have received streptomycin.

There are at present strict indications for pulmonary resection with which most surgeons are in agreement. These consist of residual cavities after thoracoplasty, post-tuberculous bronchiectasis with positive sputum, severe bronchostenosis, and tuberculomas. The patients with acute exudative disease constitute a different indication, inasmuch as other methods of treatment are usually effective. At the University of Michigan Hospital we have had no experience with resection in patients with acute exudative disease.

During the past fifteen months streptomycin has been used in conjunction with pulmonary resection in almost all of our cases. Our results have shown a distinct improvement in comparison with earlier results. We feel, however, that streptomycin has not been the sole reason for the improved results, but rather that well-chosen indications and improved technique have also played an important part. In this period of fifteen months, pulmonary resection has been done for 50 consecutive patients, all of whom presented strict indications. It is too soon to know the late results, but the early results have been encouraging. No deaths have occurred. One spread developed as a result of operation in a patient with active tuberculous bronchitis with stenosis and an inflation cavity containing retained secretions. Two late spreads occurred, but the spreads in all three cases have cleared satisfactorily. One patient developed an empyema and bronchial fistula.

Streptomycin provides an adjunct which helps particularly, as mentioned this morning, in the preparation of patients for operation. It is distinctly useful after operation should *complications occur. More especially, however, we feel that the proper choice of cases is the* important consideration at the present moment in the treatment of pulmonary tuberculosis by resection.

DR. ROBERT G. BLOCH, Chicago.—I should like to remark on the dosage of streptomycin. There has been a recent tendency to decrease the dosage to a fraction of what was prescribed during the early period of this therapy. The essential reasons for this have been the great expense of the drug and the toxic manifestations resulting from the larger doses. It is possible that the smaller doses such as ½ Gm. daily are sufficient for all therapeutic purposes; however, as yet no scientific proof for this has been offered, but we do know that not only do variants of the tubercle bacilli present in most patients become streptomycin-resistant under therapy but that some variants are naturally resistant before the beginning of treatment. The reactivations of disease after what seems to have been successful streptomycin therapy probably result from the growing out of these resistant variants. As long as there is a posibility that larger doses such as 2 Gm. daily may vigorously dispose of some of the organisms which under smaller dosage would become resistant, I recommend caution in reducing the dosage, at least during the first few weeks of treatment.

Like some others we have lately been experimenting with para-aminosalicylic acid (PAS) which was found by Lehmann in Sweden to be bacteriostatic for the tubercle bacillus. While this drug alone has a somewhat lesser effect than streptomycin alone, the two drugs given in combination have exerted a powerful bacteriostatic effect in vitro and in vivo (in guinea pigs). Further experiments and trials will be needed to establish the validity of the results so far obtained.

DR. LAURENCE MISCALL, New York.—Dr. Churchill and Dr. Klopstock, in an original paper, pointed out the desirability of the straightforward approach with primary resection in the treatment of pulmonary tuberculosis. After Dr. Klopstock left Dr. Churchill he came to Triboro Hospital where he has been working for approximately five years. In the last year we have followed their concept of the application of excisional therapy and have tried to select a continuous series of cases which seemed suitable for primary lobectomy or pneumonectomy. With streptomycin given preoperatively for that period during which the patient continues to improve, and followed routinely by ninety days of postoperative treatment, we have in the last seven months completed 31 consecutive resections, 27 lobectomies and 4 pneumonectomies. There have been no deaths nor postoperative spreads. Two fistulas which occurred were promptly closed by muscle transplant. I think they probably represent errors in operative technique. All patients are doing well, but the long-term result I cannot predict. I think that in all discussion of excisional therapy one point can be made, and I believe it runs through all the papers. Since primary resection offers not only maximal preservation of function but also an excellent possibility for cure, a greater effort should be made to use it as a procedure of choice. This can be done when the patients are very carefully evaluated. The concept of Dr. Churchill and Dr. Klopstock offers satisfactory criteria by which this procedure may be applied.

DR. O. C. BRANTIGAN, Baltimore.—The papers are unanimous in the belief that for patients with pulmonary tuberculosis the use of streptomycin makes all types of surgery much safer. Since the spread or flare-up of disease was most common with pulmonary resections, the beneficial effects of the use of streptomycin in these operations has been most noticeable. Before the use of streptomycin, lobectomy was accompanied by less flare-up or spread of disease and less morbidity and mortality than pneumonectomy. With the use of streptomycin, lobectomy for pulmonary tuberculosis is an extremely safe operation. It should be pointed out that if there is palpable disease in the remaining lobe or lobes perhaps the pneumonectomy is the better operation. Past experience has indicated that before use of streptomycin the patient who survived the pneumonectomy did not later break down with tuberculosis; whereas a high percentage of patients who had lobectomy had recurrence of pulmonary tuberculosis on the operated side, anywhere from six months to two and one-half years after lobectomy. Streptomycin should be considered an acute treatment that will influence the tuberculosis infection but probably will not eliminate the bacteria. Streptomycin, therefore, probably will have no influence on the end result of lobectomy for pulmonary tuberculosis.

DR. CLARENCE CRAFOORD, Stockholm, Sweden.—I should like to tell you that para-aminosalicylic acid, or PAS, is a drug that has been available in Sweden for more than two years for clinical use. It was the work of the Swedish scientist, Jörgen Lehmann, in 1945, which made this drug available. We have used it in series, running it parallel with the use of streptomycin, and we have found that PAS is not as effective as streptomycin in widespread acute lung cases and in cases of miliary tuberculosis and meningitis. We have also had small series in which we have first treated patients with only PAS and then with streptomycin alone, with little effect, but later with a combination of both drugs we have had quite good effect as Dr. Bloch stated. I think PAS is something that should be taken up very seriously for further study. Especially in cases of intestinal tuberculosis we have found this drug to be of great value. Another fact of importance is that the use of PAS does not seem to have any long-lasting toxic effect.

DR. MULVIHILL.—I should like to say a few words in relation to the use of streptomycin in the pleural cavity, as referred to in the experimental work of Dr. Beasley and Dr. Blades and his associates. I had a group of 4 cases, which time did not permit me to report in my paper, in which streptomycin was used in the pleural cavity in tuberculous or tuberculous-mixed-infected empyemas. These were closed spaces without bronchopleural fistulas. The first patient was given 1 Gm. of streptomycin twice a week into the pleural space after evacuation of the thick pleural fluid. The streptomycin was diluted in 100 c.c. of normal saline. The 3 other patients were given the same treatment except that the dosage was reduced to ½ Gm. diluted in 100 c.c. of saline three times a week following evacuation of pus from the pleural space. It was possible to sterilize all these pleural cavities of tubercle bacilli, in varying times. One was sterilized after twenty-two days of treatment, another in ninety days, a third in about seventy days.

The streptomycin levels in the pleural fluid, taken forty-eight to seventy-two hours after the introduction of the drug, varied greatly, from 10 to 160 millimicrograms; it seemed that the longer the duration of the treatment the greater the concentration in the pleural fluid at a forty-eight hour period after introduction. Simultaneous blood levels ranged from 5 to 10 millimicrograms irrespective of the pleural fluid concentration.

I would also like to refer to another group of 8 cases of old residual empyema spaces following Schede thoracoplasties, with bronchopleural fistulas and pleurocutaneous fistulas. In these a method of treatment with streptomycin was used in which the space was surgically uncovered, and in some cases the lung was decorticated without further mobilization. They were then left widely open. (Slides.) They were treated with a mixture of streptomycin consisting of 1 Gm. of streptomycin and 4 Gm. of dry plasma powder. The open wounds were dusted daily with this mixture, and in all cases healing with clean granulations, such as shown in this slide, was achieved. These patients were not given parenteral streptomycin. In two cases we were able to go ahead from this point and do a secondary closure with immediate healing. This method of treatment has not been previously mentioned. Appreciable blood levels were not obtainable in patients with streptomycin applied to open wounds by this method.

DR. O'BRIEN.—I would like to say one word about Dr. Bloch's discussion. He said that so far as he knew there was no scientific data available to warrant giving smaller doses of streptomycin. It is scientific enough for me to know that it is possible to get exactly the same and possibly better results with smaller doses without having cripples, hopelessly maimed, with nerve involvements, following treatment.

DR. BEATTIE.—I think the suggestion that one reason we found high levels in scarred pleuras was that the vascularity was increased, is a good one. I think it might be expected that streptomycin put into the chest at the time of operation when new tissue spaces are opened and scar is cut across would more likely give high levels than where there is an old scar and streptomycin is put in by thoracentesis. There is one other point that I think might be brought out in the use of streptomycin in the pleural cavity; that is, since the toxic effects seem to be related to the levels of streptomycin that are maintained, it would be well in putting streptomycin in the pleural cavity to be sure to give the streptomycin intrapleurally between times when the intramuscular doses are given parenterally. If a parenteral dose of streptomycin coincides with the intrapleural dose, one can see there would also be high blood levels. We intend to continue some of this work to see what other pathologic effects may be obtained with many repeated intrapleural injections of streptomycin.

DR. MURPHY.—At Oteen we have not had the experience reported by Dr. O'Brien's group in the avoidance of the necessity for surgery by the use of streptomycin. We have used this agent as an adjunct and, as in the other reports this morning have been able to operate on a number of patients by virtue of the use of streptomycin who could not have been prepared for surgery without it. There are so many other factors such as adequate blood replacement, improved pre- and postoperative care, skilled anesthesia, and the Overholt position for resection that it is difficult to place an exact valuation on streptomycin.

All our resections have been done at Oteen in the Overholt position. We did not have the new table, on display here in the lobby, and we do not wish to discourage its sale. As a matter of fact, we have just completed an order for one of these tables. We did, however, have an Albee-Compere orthopedic table and for about ten dollars we were able quickly to modify this table to the Overholt position. (Slides.) The first slide shows the modification of the table with the traction arms reversed. The second slide shows the patient in position ready for surgery.

One further factor of the use of streptomycin needs emphasis and that is that the cooperative study conducted by the Veterans Administration has shown clearly that streptomycin does produce resistance if given over a period of several weeks. This resistance is a factor of the duration of dosage rather than the amount of dosage. For this reason we should be careful and avoid giving streptomycin to patients who do not require it, as in routine thoracoplasty, so that we do not deprive them of its protection if a resection is necessary.

AN ANATOMIC APPROACH TO SEGMENTAL RESECTION

J. GORDON SCANNELL, M.D. (BY INVITATION)
BOSTON, MASS.

TECHNICAL application of the principles of segmental resection has required a precise knowledge of the anatomy of the lung. As individual ligation evolved from mass ligature of the hilar structures, so the more elaborate and unhurried dissection required for segmental resection has developed from the individual ligation technique. Granted that conservation of normal lung tissue is desirable, segmental resection may, under certain circumstances, be the operation of choice. Manifestly, the nature of the pathology involved or merely local technical considerations may preclude that choice. It is not intended here to measure ultimate gain against possible hazard in terms of increased operative time and difficulties with the carefully preserved remnant, but rather to consider segmental resection in terms of the surgical anatomy involved and the growing body of knowledge in that regard.

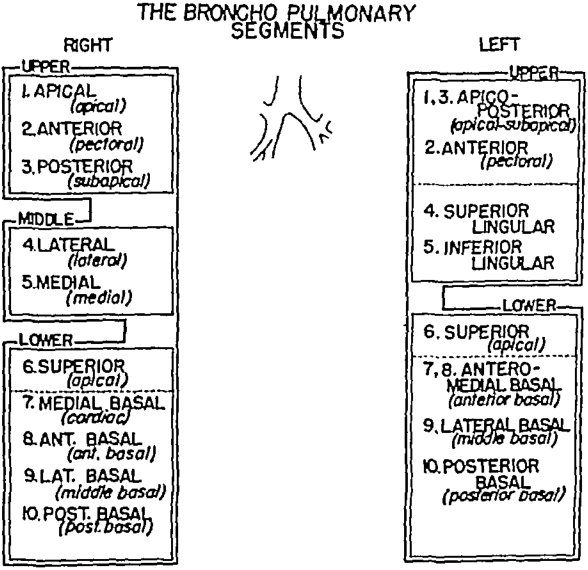
In 1939, Churchill and Belsey[8] argued that "solely as a concession to operative technics, the lobe has been considered the surgical unit of the lung. The very name of the operation of lobectomy indicates the general acceptance of this concept. A lobe of the lung, however, is in reality made up of a cluster of bronchopulmonary segments." It was recommended that, in bronchiectasis, the segment replace the lobe as the surgical unit.

The concept of the pulmonary segment owes its origin to William Ewart,[10] Victorian physician and pathologist, who, in 1889, ascribed to each lung nine primary "bronchial districts." As Boyden[3] has pointed out, a distinctive feature of Ewart's work was his recognition of the fact that "the lung must be divided into yet smaller regions (than the lobes) in order to attain simplicity in description" and furthermore that these "districts" represented anatomic entities. Ewart's work suffered from a top-heavy mass of detail but remained the only accessible "information concerning the general arrangement of parts within the lung" until 1932. In that year Kramer and Glass[14] rediscovered the primary bronchial districts and applied to them the term "bronchopulmonary segments." Two years later, Nelson,[15] in order to furnish an anatomic basis for postural drainage, described their topography. His description was generally accepted in the English-speaking medical world until, in the past five years, more extensive studies have led to its revision. From the most important of these (Jackson and Huber,[13] Brock,[7] Boyden,[3] Foster-Carter,[11] Appleton,[1] all of which are in virtual agreement as to the disposition of the segments, the simplified schedule shown in Fig. 1 has been drawn up. The need for a generally accepted nomenclature is obvious. At present that of Jackson and Huber, based upon the position of the segment within the lobe, seems to be the most satisfactory.

From the Massachusetts General Hospital and Harvard Medical School.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

Although considerable work has been done relative to the bronchial anatomy of the segment, less material has been available concerning its vascular component. So long as thoracic surgery was concerned chiefly with the chest wall and the localization of pulmonary cavities, the need for detailed information concerning the vascular arrangements within the lung was not great. However, as resection of lung tissue underwent its technical development, the need for more precise knowledge became apparent. The stimulus to extend that knowledge from lobe to segment came with the 1939 paper of Churchill and Belsey, previously quoted. At that time the precise anatomy of the lingular bronchus, artery, and vein was described in conjunction with the technique of lingulectomy. Furthermore, the extension of the general principle of segmental resection was advocated and specific suggestions were made relative to the superior and basal segments of the lower lobes on the basis of experience already acquired. In subsequent years, segmental resection of the lingula and of the basal segments considered as a unit have become standard operative procedure, finding particular application in the treatment of bronchiectasis. Other segments than these have also been removed separately where conditions have


THE BRONCHO PULMONARY SEGMENTS
RIGHT
UPPER
1. APICAL (apical)
2. ANTERIOR (pectoral)
3. POSTERIOR (subapical)
MIDDLE
4. LATERAL (lateral)
5. MEDIAL (medial)
LOWER
6. SUPERIOR (apical)
7. MEDIAL BASAL (cardiac)
8. ANT. BASAL (ant. basal)
9. LAT. BASAL (middle basal)
10. POST. BASAL (post. basal)
LEFT
UPPER
1, 3. APICO-POSTERIOR (apical-subapical)
2. ANTERIOR (pectoral)
4. SUPERIOR LINGULAR
5. INFERIOR LINGULAR
LOWER
6. SUPERIOR (apical)
7, 8. ANTERO-MEDIAL BASAL (anterior basal)
9. LATERAL BASAL (middle basal)
10. POSTERIOR BASAL (posterior basal)

Nomenclature by Jackson and Huber, 1943
Enumeration by Boyden, 1945
Brock's (1946) nomenclature in parentheses
Bronchoscopically, all these segments, with the possible exception of 4 and 5, should be identifiable with precision.

Fig. 1.—Simplified schedule of the bronchopulmonary segments.

warranted, and have been reported from time in the surgical literature.[10, 12] Two such cases—one an anterior segment of left upper lobe, the other a medial basal segment of right lower—have been chosen as clinical examples for the present communication.

These two examples have been selected to call attention to certain anatomic studies in which a method of precise description of intrahilar anatomy has been employed. There are few short cuts to mastery of "segmental anatomy" other than by way of the dissecting room and the operating table, and it is in conjunction with these that the source materials supplied by Boyden can best be appreciated. In an extensive series of dissections[5, 6] this author described and correlated bronchi, arteries, and veins in terms of a prevailing pattern and common variations thereof. It is obvious from studying Boyden's material that few anatomic rules of thumb can be set down concerning the segment but; on the other hand, certain fairly consistent pattern complexes are described that are of considerable practical value in planning resection of a given segment. Predictions as to the resectability of a segment will always be subject to modification by the anatomy and pathology of the local situation found at thoracotomy. However, accurate knowledge of the usual pattern and the common variations is essential to carrying out segmental resection when it is found to be feasible.

In addition to a presentation of the common pattern and variations therein, other aspects of Boyden's work are of surgical importance. He has confirmed the fact that the segment, so far as the pulmonary arterial supply is concerned, is a bronchovascular unit, although at the level of the hilum the pattern of each component must be worked out individually. The pulmonary veins, on the other hand, are intersegmental in nature and more variable than the arteries in their patterns. The bronchial arteries fortunately pose no technical problem at the level of the segment.

Of special interest to the surgeon is the grouping of arteries to the right upper lobe into "recurrent" and "ascending" branches. The former are found in the course of an anterior dissection of the hilum where they are usually deep to the apical and anterior branches of the superior pulmonary vein. The "ascending" arteries to the upper lobe are to be found at the base of the fissure, where they spring from the interlobar portion of the pulmonary artery to supply portions of the posterior and/or anterior segment. Appleton,[2] who introduced the terms "recurrent" and "ascending," has emphasized the variable relationship of the latter to the interlobar division of the posterior vein of the upper lobe.

In the left upper lobe, not infrequently a branch of the lingular artery is found supplying the posterior ramus of the anterior segment (36 per cent of 50 specimens, Boyden[5]). Boyden has considered this to be one of the anatomic hazards of lingulectomy.[4]

To date, Boyden's studies are "complete" only for the upper lobes, while the lower and middle lobes are at present under scrutiny. It seems probable, however, that the upper and middle lobes, together with the medial basal and superior segments of the lower lobes, will prove most amenable to segmental resection. The disposition of the basal segments makes difficult their differentiation, anatomically, radiologically, and surgically.

CASE 1.—The first of the two clinical examples to be considered was a 35-year-old housewife who, five months prior to admission to the Massachusetts General Hospital, had been ill with lung abscess (Fig. 2). Treatment elsewhere had consisted of bed rest, general supportive therapy, and aerosol and intramuscular penicillin. Symptoms of cough, hemoptysis,

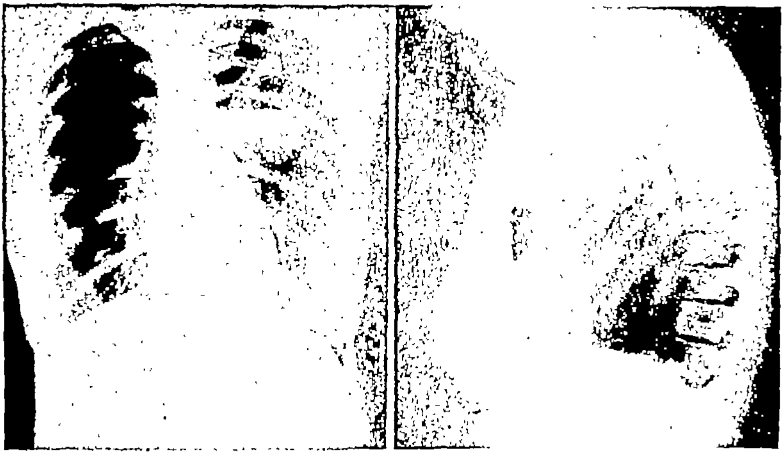


Fig. 2 (Case 1).—Posteroanterior and lateral films taken at the time of the patient's acute symptoms of lung abscess. The anterior segment of the left upper lobe is clearly outlined by disease.

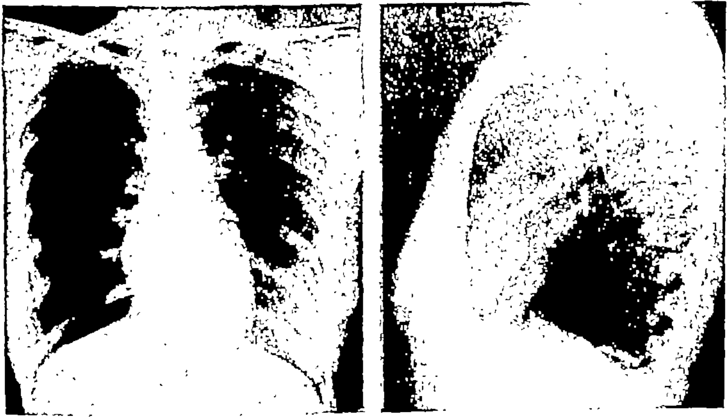


Fig. 3 (Case 1).—Posteroanterior and lateral films that demonstrate the persistent thin-walled cavity localized to anterior segment of left upper lobe.

and fever had subsided, but x-ray examination showed a large, thin-walled cavity to persist in the anterior segment of the left upper lobe (Fig. 3). Operation was advised on the basis that this represented a potential focus of severe, recurrent infection. In view of the localized nature of the disease, a conservative resection was proposed.

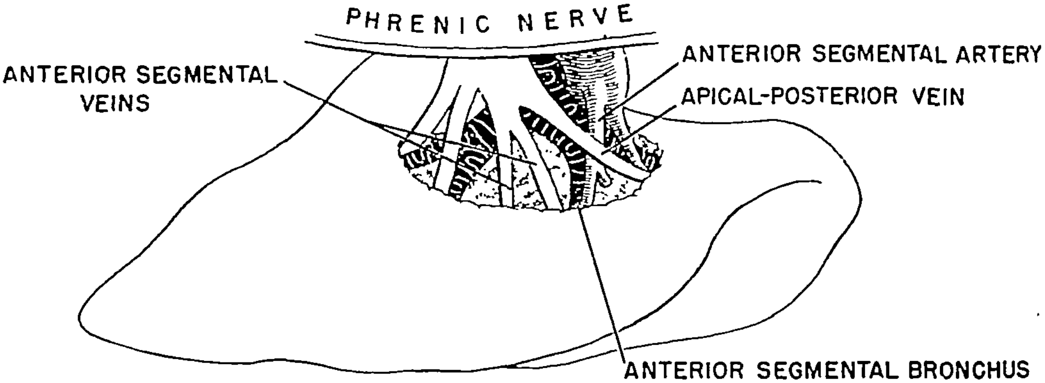


Fig. 4 (Case 1).—The extent of the anterior hilar dissection at the time of operation. Division of the anterior segmental veins afforded access to the lobar bronchus. The anterior segmental artery and bronchus were divided after retraction of the apical-posterior vein.

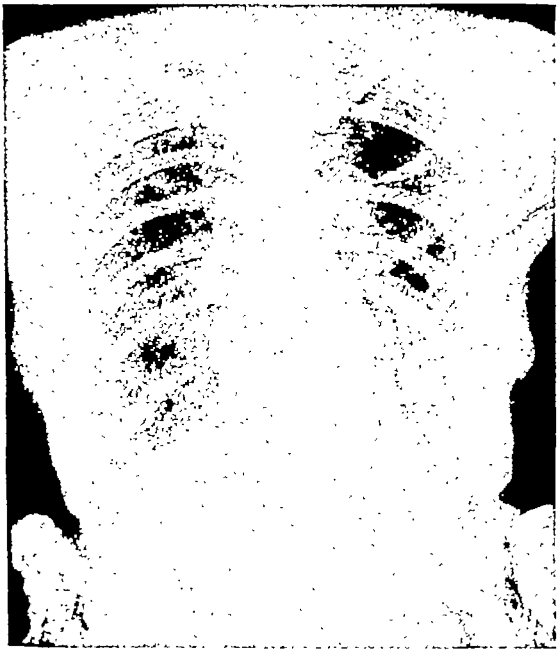


Fig. 5 (Case 1).—One year postoperative. A linear scar is apparent at the site of resection of the anterior segment of left upper lobe.

At the time of thoracotomy, adequate exposure was obtained by resection of the sixth rib. The pleural space was observed to be free of adhesions except over the anterior segment of the left upper lobe, and these were readily divided by sharp dissection. The remainder of the left upper lobe appeared essentially normal. The oblique fissure was anatomically complete.

Dissection of the hilum at the base of the fissure demonstrated the lingular artery, which, in this instance, furnished a small branch to the posterior aspect of the anterior segment. The arch of the pulmonary artery was followed upward over the left upper lobe bronchus and arterial branches to apical-posterior and anterior segments accurately identified (Fig. 4). All the subdivisions of the superior pulmonary vein, lying on the anterior aspect of the hilum, were exposed and the apical-posterior vein was retracted upward to afford access to the anterior segmental artery. The anterior segmental branches of the vein were divided, one large lymph node dissected out of the crotch of the upper lobe bronchus, and the superior division of this bronchus exposed. After division of the anterior segmental artery, the superior bronchial division could be followed outward to its bifurcation into anterior and apical-posterior branches. The anterior branch was gently occluded and, by inflation of the lung, demonstrated to supply the area of disease. It was therefore divided, closed with interrupted fine silk sutures, and, after incision of the pleura along the line demarcated by inflation, the segment removed from below upward without clamps.[16] A few hemostatic and aerostatic sutures of fine silk were necessary. The wedge-shaped defect in the lobe was closed by approximating the upper surface of the lingula to the apicoposterior segment, a manœuvre that covered the bronchial stump with normal lung.

Postoperatively the patient expanded the left upper and left lower lobes well, both clinically and by x-ray. The latter revealed a circumscribed area of density in the region of the resection which was interpreted as probably hematoma, possibly infarction. One year later this was demonstrated as a linear scar (Fig. 5). Clinically, the patient is well.

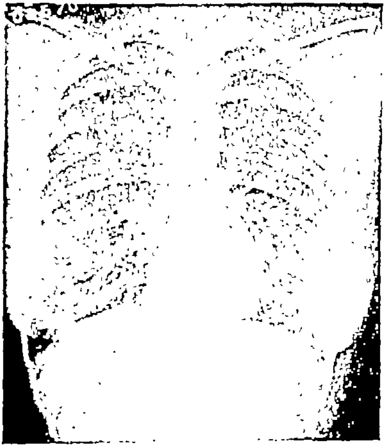


Fig. 6 (Case 2).—Posteroanterior bronchogram demonstrating bronchiectasis in medial segment of right middle lobe, medial basal segment of right lower, and inferior lingular segment of left upper lobe. This localization was confirmed by a right lateral view and right and left oblique views not shown.

Case 2.—The second example was that of a 14-year-old schoolgirl with bilateral bronchiectasis. Since the age of 3 years the patient had been prey to frequent bouts of upper respiratory infection, which had become almost continuous. She raised, on the average, one-half to one "cup" of yellowish, tenacious sputum daily. She had managed to keep up at school, but bore many of the psychologic stigmas of the disease.

Plain films showed bilateral disease in both lower lung fields. A bronchogram demonstrated bronchiectasis in the medial segment of the right middle lobe, the medial basal segment of the right lower lobe, and inferior lingula segment of the left upper lobe. No disease could be demonstrated in the basal segments of the left lower lobe.

Prior to operation, bronchoscopy was carried out. A normal right upper lobe orifice was inspected through a right-angle lens and a trifurcation visualized. The mucosa about the middle lobe orifice was somewhat thickened and considerable mucopurulent sputum could be seen coming from it. The orifices of the superior segment and basal segments of the right lower lobe were normal except the medial basal orifice, from which considerable pus exuded. The left bronchial tree was examined and no abnormalities were noted.

After suitable preparation, a right thoracotomy was performed. Resection of the sixth rib gave excellent exposure. The pleural cavity was essentially free of adhesions except at the anterior tip of the middle lobe. The fissures were well developed except for anatomic fusion of the anterior half of the minor fissure. A middle lobectomy was carried out. The line of demarcation between middle and upper lobe was demonstrated by inflation, and the lobes were divided by stripping from below upward. A small apron of pleura was fashioned from the middle lobe to cover the resultant raw area in which there was no significant bleeding or air leak.

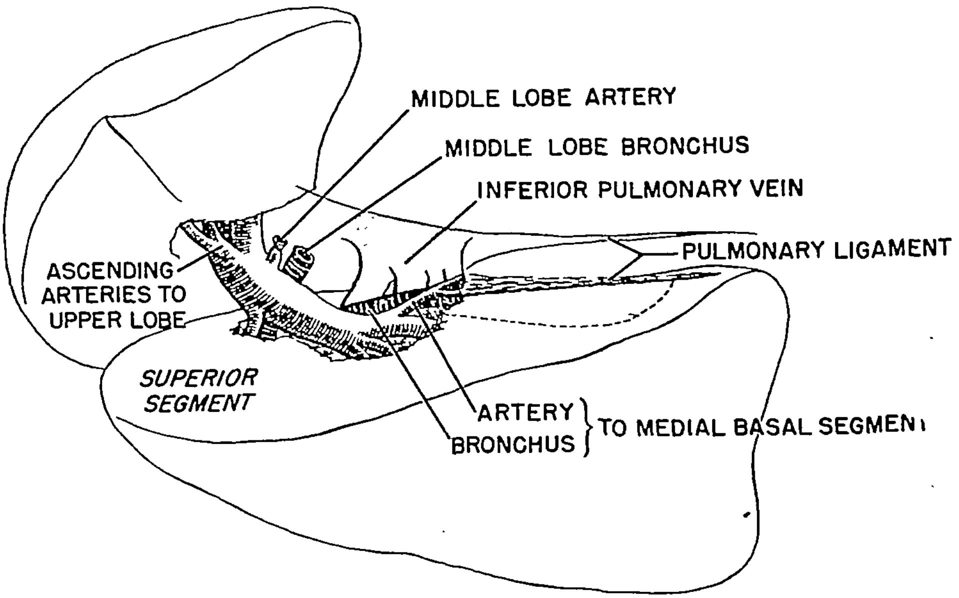


Fig. 7 (Case 2).—Operative sketch. The middle lobe has been removed. The relationship of the artery, bronchus, and veins to medial basal segment of right lower lobe is shown. The surface area of that segment and its relationship to pulmonary ligament are indicated by a broken line.

Attention was then directed to the lower lobe which appeared entirely normal except for a collapsed, inelastic medial basal segment, which lay just anterior to and beneath the pulmonary ligament. The dissection was started along the pulmonary artery and the large anterior basal branch to the lower lobe demonstrated (Fig. 7). Springing from its medial aspect was a sizable branch that supplied the medial basal segment. This was divided. The pulmonary ligament was divided up to the inferior pulmonary vein. This lay in the plane between medial and posterior basal segments, and no surface tributaries from the medial basal segment were observed. The anterior surface of the vein was exposed and a few branches crossing this plane were divided and ligated. The medial basal bronchus was then readily exposed as it emerged from beneath the pulmonary artery. The bronchus was divided, closed with interrupted silk, and the segment readily stripped from the remaining basal segments of the lower lobe. There was relatively little bleeding and no air leak. The resulting defect tended to fold over on itself and few sutures were required. The bronchus lay covered within the substance of the lung.

The patient's postoperative course was satisfactory, with excellent expansion of both upper and lower lobes.

In the two cases selected, the indications for segmental resection seemed clear, and the local situation, particularly with regard to the completeness of the fissures and lack of acute inflammation, favorable. In both, the anatomic patterns were straightforward.

In the first case, the anterior origin of the arteries was as expected. According to Boyden and Hartmann, the artery to the anterior and lateral portions of the anterior segment arises consistently from the pars anterior of the left pulmonary artery. In about one-third of specimens, as here, the apical artery also has an anterior origin. The branching of the superior pulmonary vein is worthy of comment, first in regard to the anterior and relatively superficial position of its branches, and second, in regard to the presence of two branches to the anterior segment.

In the second case, the accessibility of the pulmonary artery as it lay on the anterior aspect of the right lower lobe was striking. The relation of the medial basal segment to the pulmonary ligament was in accord with Brock's description of the "cardiac" segment. It is this segment that forms a separate "cardiac" lobe in most quadrupeds, and in man is not infrequently marked by an incisure (24 per cent).* In the case described, its relation to the inferior pulmonary vein was the key to the situation.

SUMMARY

1. The significance of the bronchopulmonary segment has been reviewed with reference to segmental resection of the lung.
2. Recent studies of bronchovascular anatomy have been discussed.
3. Segmental resection of the anterior segment of the left upper lobe and medial basal segment of the right lower lobe have been presented with illustrative cases of each. Emphasis has been laid on the problems of surgical anatomy involved.

REFERENCES

1. Appleton, A. B.: Segments and Blood Vessels of the Lung, Lancet 2: 592, 1944.
2. Appleton, A. B.: The Arteries and Veins of the Lungs. I. The Right Upper Lobe, J. Anat. 79: 97, 1945.
3. Boyden, E. A.: The Intrahilar and Related Segmental Anatomy of the Lung, Surgery 18: 706, 1945.
4. Boyden, E. A.: The Anatomical Hazards of Lingulectomy, Surgery 20: 828, 1946.
5. Boyden, E. A., and Hartmann, J. F.: An Analysis of Variations in the Bronchopulmonary Segments of the Left Upper Lobes of Fifty Lungs, Am. J. Anat. 79: 321, 1946.
6. Boyden, E. A., and Scannell, J. G.: An Analysis of Variations in the Bronchovascular Pattern of the Right Upper Lobe of Fifty Lungs, Am. J. Anat. 82: 27, 1948.
7. Brock, R. C.: *The Anatomy of the Bronchial Tree*, London, 1946, Oxford University Press.
8. Churchill, E. D., and Belsey, R.: Segmental Pneumonectomy in Bronchiectasis, Ann. Surg. 109: 481, 1939.
9. Churchill, E. D.: Resection of the Lung, Surgery 8: 961, 1940.
10. Ewart, W.: The Bronchi and Pulmonary Blood Vessels, London, 1889.
11. Foster-Carter, A. F.: The Anatomy of the Bronchial Tree, Brit. J. Tuberc. 36: 19, 1942.
12. Glover, R. P., and Claggett, O. T.: Pulmonary Resection for Abscess of the Lung, Surg., Gynec., & Obst. 86: 385, 1948.
13. Jackson, C. L., and Huber, J. F.: Correlated Applied Anatomy of the Bronchial Tree and Lungs With a System of Nomenclature, Dis. of Chest 9: 1, 1943.
14. Kramer, R., and Glass, A.: Bronchoscopic Localization of Lung Abscess, Ann. Otol., Rhin. & Laryng. 41: 1210, 1932.
15. Nelson, H. P.: *Postural Drainage of the Lungs*, Brit. M. J. 2: 251, 1934.
16. Overholt, R.: A New Technique for Pulmonary Segmental Resection, Surg., Gynec. & Obst. 84: 257, 1947.

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*Reported by Dr. Franklin Smith at a meeting of the American Association of Anatomists, 1948.

DISCUSSION

DR. ROBERT KLOPSTOCK, Jamaica, N. Y.—I have been fortunate and privileged to be associated with Dr. Churchill from 1939 to 1942, and to carry on studies under his guidance and stimulation, on the surgical pathology of the lung. These studies revealed, among others, that the distribution of the chronic surgical diseases of the lung—including chronic tuberculosis—has corresponded with the bronchovascular segment of the lung.

The localization and the radiographic analysis of pathologic processes in the chest could be improved greatly by using body-section radiography in the anteroposterior view. But even this method fails to demonstrate clearly the segmental and lobar distribution of the pathology present because it does not resolve the overlapping of the bronchovascular segments as visualized in the anteroposterior plane, for the branching of the bronchovascular structures takes place, rather, in the sagittal plane. Therefore, the lateral body-section radiography was devised by Mr. J. L. Mathias and myself in 1943, and has been used since at the Triborò Hospital, Jamaica, N. Y. Each patient considered for any type of surgery for disease of the lung was hence tomographed both in the anteroposterior *and* in the lateral view. This method was found most satisfactory to reveal pathologic conditions of the chest and of the lung in particular, with a clarity not previously achieved, as follows: (1) Hidden hilar and parahilar pathology. (2) The lobar and segmental distribution of chronic pulmonary disease with particular attention to the apex of the lower lobe, the middle lobe, the lingula: (a) in cases of tuberculosis *the* information necessary if lobectomy has to be considered vs. thoracoplasty or (b) in most carefully selected cases if lobectomy with resection of adjacent diseased segment has to be considered, or (c) if resection of a diseased individual segment alone is considered, (d) in cases of bronchiectasis both obviating bronchography in many instances and delineating the involved segments to be resected individually. (3) The relation of the site of the disease to the fissures, also with particular attention in cases of pulmonary tuberculosis if lobectomy has to be considered. (4) The demarcation of the relative volume of lobes involved and uninvolved by disease with particular attention to the pathophysiologic considerations. (5) The differentiation of a given intrathoracic pathology as to its localization in- or outside of pulmonary parenchyma. (6) Possibilities in the study of coarctation of the aorta, patent ductus arteriosus, arteriovenous fistulas of the lung, aneurysma of the great vessels.

Having this information of a more correctly interpreted pathology, a planned outline of the respective surgical procedure can be drawn. (Slides.)

DR. RICHARD H. OVERHOLT, Boston.—I am sure a great many future patients suffering from bilateral pulmonary disease will appreciate the help they will receive because of the surgeon's ability to remove segments. They will unconsciously thank such pioneers as Drs. Churchill, Belsey, Boyden, Blades, Nelson, and Scannell, who has again brought this important concept of treatment to our attention.

When we first became interested in segmental resection, it was applied only in patients suffering from bilateral disease, for in them any loss of functioning pulmonary tissue might compromise a satisfactory result. However, as time went on, with greater knowledge of the anatomy of the various segments and improved technique in developing the intersegmental plane, which resulted in fewer complications, it has been possible to utilize individual segments as the unit of excision in certain cases of unilateral bronchiectasis and in other conditions as well.

(Slides.) I should like to relate circumstances in one case which will illustrate why it is important to limit the resection to segments when possible in unilateral disease. Recently this patient presented himself with a giant cyst in the right lung which had caused almost a total collapse of that lung. Upon exploration, it was found that the cyst represented a check valve mechanism in one of the subsegments of the upper lobe. The resection was therefore limited to that subsegment and you will see (slide) the appearance both before and after the removal of the subsegment which contained the cyst. In the next film (slide) you will see a routine follow-up x-ray view which was taken when the patient reported to his doctor six months later. At this time an abnormal shadow was found in the left upper lobe which turned out to be a primary carcinoma. If we had originally used a lobe for the unit of excision in the treatment of the cyst on the right, we would have closed the door to treatment of the carcinoma which subsequently developed in the left lung.

Gradually the principle of segmental excision has been extended to include almost every one of the eighteen segments. It has been possible to remove them individually or in groups. In this slide are illustrated various segments which have been removed and the condition for which the operation was performed—bronchiectasis, tuberculoma, solitary tuberculous cavity, metastatic tumor, abscess, cyst, and benign tumor.

It is timely to project a thought about segmental resection in tuberculosis. Not infrequently the superior segment of the lower lobe is found to be involved when exploration is done for upper lobe disease. In that event it is preferable to include that segement in the resection with upper lobectomy rather than abandon resection or resort to pneumonectomy. We have also had occasion to do a more limited resection than previously planned. A superior or posterior segment may contain all the gross tuberculosis disease and a segmental resection may suffice. It is too early to comment on end results. In tuberculous subjects the resection has been limited to segments in nine cases. From this early experience it would seem that, in the future, segmental resection will have a definite place.

DR. F. A. HUGHES, Memphis.—I have been interested in segmental resection and also a combination of streptomycin and resection, and I believe it stands a good chance of greatly improving the treatment of certain cases of tuberculosis. Recently, we have done three segmental resections for tuberculosis. We find in some cases it is preferable not to do the usual initial hilar dissection of the segment, but to start the dissection of the pathology peripherally. In contrast to bronchiectasis, it is usually possible to demonstrate at the operating table the extent of the lesion. Recently we resected the posterior-apical and anterior segment of the upper lobe and the superior segment of the lower lobe. The cavity in the superior segment was draped over the artery to the basal segments. The patient surprisingly had an airtight remnant after the operation and has made an uneventful recovery to date. Apparently selective resection, with the protection of streptomycin, will hasten recovery without the necessity for as extensive or as radical a thoracoplasty.

DR. OSLER ABBOTT, Atlanta, Ga.—I want to mention one thing which has been under discussion in segmental resection, that is, closure of the defect on the left. When we were first presented with this method, considerable discussion arose in regard to the method of closure. If a cleft were left so that there was a tendency for the lung to close without distortion, that should be done. Others feel that it restricted pulmonary activity. I have been disappointed with fibrin foam or any coagulating material in the cavity, because of an occasional instance of clotting hemothorax. I was very much opposed to leaving a raw area, and have done subsequent series with and without closure of the raw area. I think with the surface exposed great attention should be paid to pulmonary function, and it seems to be improved when no attempts are made at closure. Also, other remaining segments should be sutured to the remaining intact lobe, above in order to prevent rotation of the preserved segment with associated obstruction to the segmental bronchus.

DR. ARTHUR S. W. TOUROFF, New York.—The presentation that we have just heard sets forth in detail a method which permits us to correct not only a number of conditions that occur spontaneously, but also several that follow operation. I was particularly interested in Dr. Scannell's paper from the viewpoint of correcting some of the poor results which we have had following surgical treatment of abscess of the lung. Prior to World War II, Dr. Neuhof and I published a series of papers concerning the afore-mentioned subject and it was our impression, based upon the follow-up observations that we had made up to that time, that early operation in cases of acute putrid pulmonary abscess was almost invariably followed by prompt and permanent cure. Recently, I reviewed all of our material and found that we had operated upon 154 patients with acute putrid abscess of the lung prior to Jan. 1, 1943. There were 4 operative deaths and 150 surviving patients. Forty-two of the latter could not be followed for the minimum period of five years, which was set as the basis of the study, and therefore were eliminated from further consideration. This left 108 patients who could be followed for at least five years. Of the 108 cases, 93 are well. However, much to our surprise, there were 15 patients who were left with residual postoperative pulmonary cavities or bronchiectasis. It came as a distinct shock to me to learn that 15 of 108 surviving patients were not cured. While not all of the 15 patients presented symptoms, they all had demonstrable, localized structural changes in the lung. Accordingly, I would like to retract the statement which I made prior to the War, to the effect that early operation in cases of acute putrid pulmonary abscess almost invariably is followed by complete and permanent cure. This was an error which was due to the fact that our period of follow-up observation was too short. Dr. Scannell has emphasized the value of segmental resection, and I think that the latter offers us a simple method of correcting some of the poor results that we have had following the surgical treatment of certain types of pulmonary infection.

A TECHNIQUE FOR PULMONARY SEGMENTAL DELINEATION

LAURENCE H. RUBENSTEIN, M.D.* (BY INVITATION), THOMAS J. E. O'NEILL, M.D.† (BY INVITATION), AND ROBERT P. GLOVER, M.D.† (BY INVITATION)
PHILADELPHIA, PA.

PULMONARY surgery has made rapid and steady progress from the earlier days of large mass ligature of hilar structures to this day of careful segmental delineation and resection. A clearer understanding of the anatomic relationships of lung structures, more refined surgical technique, and better anesthesia have all aided in this progressive trend.

Bronchopulmonary segments of the lungs are clear-cut entities, well described and recognized. The widely adopted nomenclature of Jackson and Huber[1] is becoming more familiar and clearly defines these segments (see Fig. 1). The segments have their independent hilar bronchovascular structures which resemble the main hilar structures of the lung. Thus, the left lung has two main lobes, the upper and lower. These are further subdivided. The upper lobe bears the following segments; an apicoposterior, an anterior, and the lingula—the homologue of the middle lobe (which is further divided into an inferior and superior division). The lower lobe gives off a superior segment, and four basal segments; anterior, posterior, medial, and lateral. Similarly segmented is the right lung, which has an upper lobe, middle, and lower lobe. The upper lobe is divided into three segments: the apical, anterior, and posterior. The middle lobe is divided into lateral and medial segments, while the lower lobe gives off a superior segment and the basal segments—anterior, medial, lateral, and posterior.

Pathologically, these segments may be a localized seat of infection. Bronchiectasis very commonly is confined to segmental distribution. Pulmonary abscess, cystic disease, and tuberculosis may be located essentially within a bronchopulmonary segment. Pulmonary disease is frequently bilateral and since we are primarily interested in effecting a cure with minimal sacrifice of good functional lung tissue, a careful study to localize the disease processes within pulmonary segments is of prime importance. Bronchiectasis, for example, which is so commonly a segmental disease with bilateral distribution, should be studied by careful bronchography. It will be found that the most frequently infected segments are: (1) on the left, the lingula and the basal segments of the lower lobe; (2) on the right, the middle lobe and the basal segments of the lower lobe. Thus, the superior divisions of the lower lobe bronchi can often be saved, which is a sizable area of good functioning lung tissue. Similarly, it is often found that only a portion of the basal segments shows pathologic change, and again, it is important to save as much good lung tissue as possible and to remove only the areas of pathology.

This paper was added to the official program of the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948, because of its pertinence to the general subject of segmental surgery.—Editor.

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Until recently the techniques for resection of isolated pulmonary pathology have been very crude. They have consisted for the most part of a "clamp-cut" method across pulmonary tissue, only presumed to be anatomic. This technique is associated with many disadvantages. In the first place, often, either too much or too little lung tissue is removed. Furthermore, it is unnecessarily traumatic, and excess tissue is destroyed by the crushing of clamps and the suturing of bleeding points. Finally, it is not anatomic.

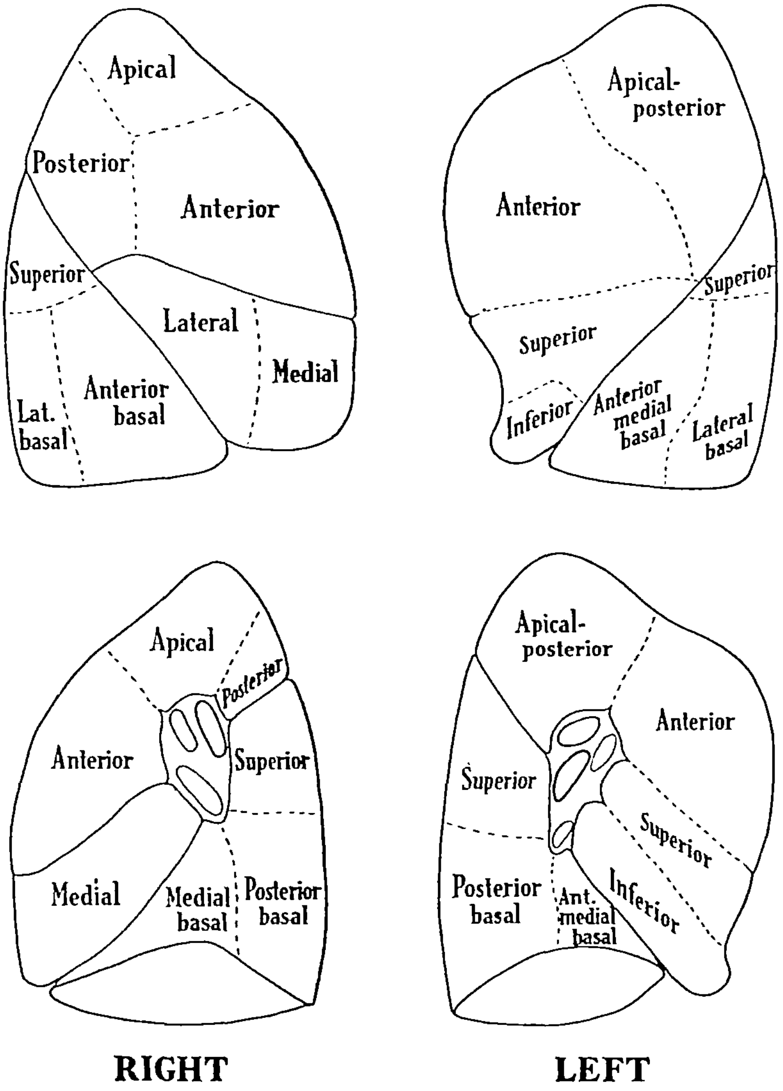

Fig. 1.—The bronchopulmonary segments. (From Jackson, C. L., and Huber, J. F.: Dis. of Chest 9: 322, 1948.

More recently, the anatomic approach has been used. Churchill and Belsey, and Overholt and Langer[2] have recently described their excellent techniques for segmental resection, utilizing the traction-dissection and differential inflation methods. Others, including Clagett and Deterling,[3] have adopted the anatomic approach.

The technique we employ closely resembles that of Overholt's up to a certain point. Exact identification and severance of the bronchus, arteries, and veins belonging to a specific segment permit subsequent surgical removal of the segment. For example, if the disease process involves the basal segments of the left lower lobe, the common basal bronchus is identified as a continuation of the left main bronchus after the superior division bronchus has been given off. This is divided and a metal suction tip is introduced into the proximal cut bronchus and directed toward the accessible bronchi, aspirating the secretions from the tracheobronchial tree. The proximal stump is closed with interrupted end sutures of No. 35 stainless steel wire on swedged needles. A clamp is kept on the distal bronchial stump. The segmental artery to the basal divisions is identified. It is merely the distal continuation of the left main pulmonary artery after the superior division branch and the lingular branch have divided. The artery is doubly ligated with No. 40 cotton. The veins from the basal segment, usually three or four in number, can be traced to the inferior pulmonary vein, at which point they are divided and ligated with No. 40 cotton. Up to this point our technique is similar to the usually described methods. In our experience the line of cleavage between segments has not always been clear cut. Whereas in some cases this cleavage can be accurately established, it is in the less diseased segments that accurate demarcation is often impossible to ascertain. The method usually employed in such cases is to inflate the lung differentially. That is, the bronchus to the diseased segments is occluded or severed and the remaining portion of the lung is inflated by positive pressure exerted on the gas machine bag. The occluded segment is expected to remain airless, but what is commonly seen is that a sharp line of differentiation between aereated lung and the occluded segment does not exist. Air does cross these intersegmental fissures, apparently by means of small air passages (Kohn's pores), and as a result, even the segment which has been occluded may become partially or completely inflated with air. One is then faced with a real problem as to how to establish the visceral intersegmental cleavage plane.

Clagett and Deterling have described the technique of stripping the bronchus and vessels with traction dissection and thus bluntly establishing a plane of cleavage. This plane of cleavage is an area which gives the least resistance to blunt dissection. Again, while this technique can often be employed, it is not infrequently seen that when removing segments, especially the smaller ones, portions of adjacent segments are torn off, or, smaller bronchi of the same segment are torn leaving portions of that diseased segment attached to the remaining lung. In this situation more bleeding is encountered.

Recognizing the occasional difficulty met in attempting to establish a clear-cut line of delineation between segments, we have employed a simple method of distending and staining the diseased segment so that it stands out clearly from the other segments. This method, while not routinely employed in our segmental dissections, is, however, found to be valuable when a clear line of cleavage is not discernible.

TECHNIQUE

Methylene blue as the coloring stain is mixed with hydrogen peroxide. A few drops of methylene blue are added to 15 c.c. of hydrogen peroxide. The resulting solution is then slowly injected into the distal (cut) bronchus of the segment to be resected. No pressure is necessary to force this solution to reach the ramifications of the segment. The action of the hydrogen peroxide, when it is in contact with the tissues, is to liberate oxygen, which then bubbles and fizzes and pushes the colored solution throughout the segment. This results in a blue-stained segment which is turgidly distended by the large amount of oxygen liberated within its tissues (Figs. 2 and 3). This segment then stands out clearly and unmistakably from the adjacent normal lung tissue. The line of delineation between the segments is well established. Since the bronchus and vessels of the segment have already been divided, the segment can now be dissected with relative ease. Furthermore, if there is any doubt about the exact vessels which supply the segment, division of these can be deferred until the staining-distention exposes their distribution.

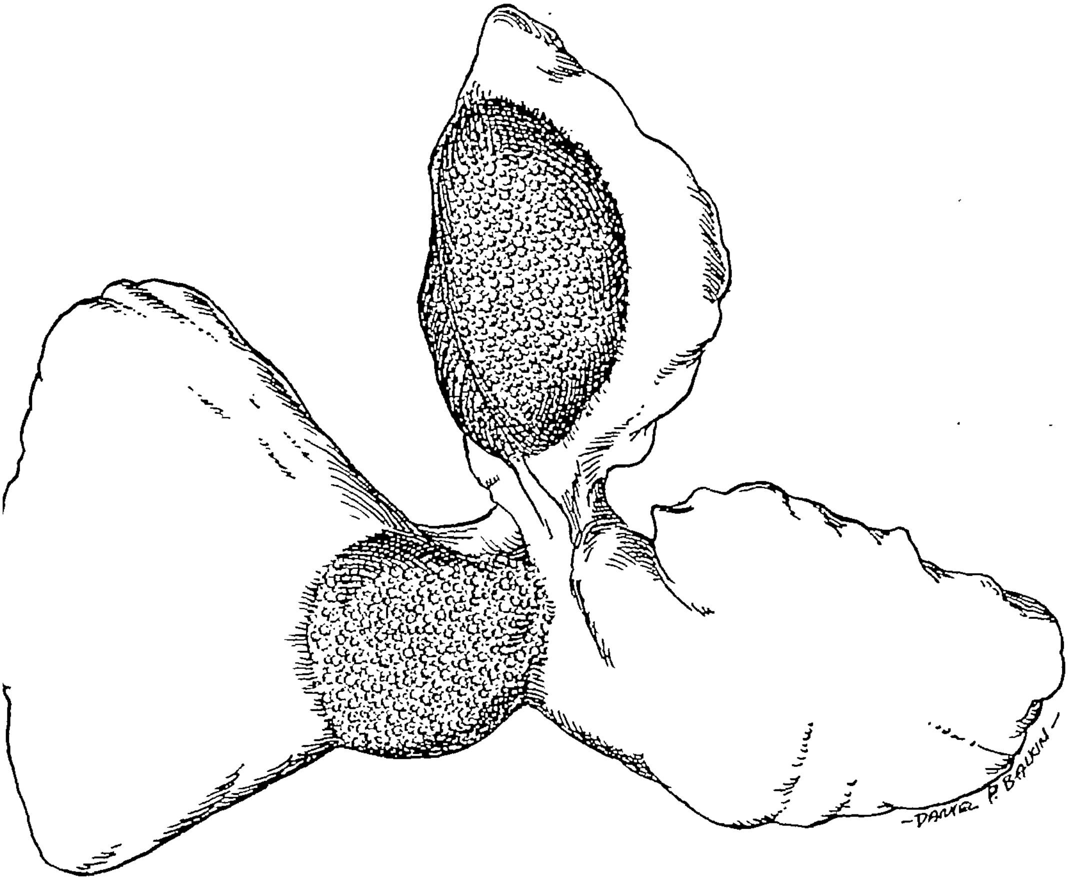

Fig. 2.—Shaded area indicates segments of dog lung distended with peroxide (H_2O_2) and methylene blue.

Details of Technique.—

1. It is preferable not to crush the distal bronchus with a clamp, but rather to occlude it gently.

2. A special adaptor has been used, devised by Dr. Louis R. Davidson, of New York, which fits tightly into the lumen of the bronchus and is equipped with a stopcock. This, furthermore, fits into a Luer Lok syringe so that no spillage occurs.

3. Excess pressure should be avoided when injecting the solution because this will cause soiling of the surrounding tissues by spilling over.

4. When removing the adaptor, a clamp should be laid ready in place over the bronchus for immediate closure to avoid regurgitation.

5. Wet sponges should be placed to wall-off surrounding tissues in the event that spillage might occur.

6. To separate the segment, blunt and sharp dissectors are usually employed. Much of the dissection is blunt (finger dissection). Very little bleeding and very little air leakage results when the proper cleavage is developed. The raw surface of lung remaining is covered with a warm moist sponge for a few minutes. It is surprising to note that this surface is relatively dry and has a minimal amount of air leak.

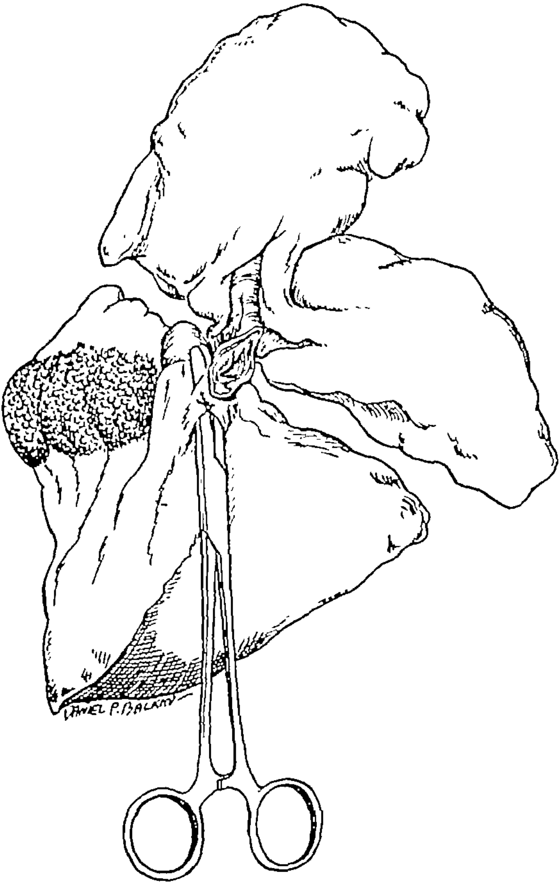

Fig. 3.—Segment of dog lung distended with peroxide (H_2O_2) and methylene blue. Clamp occludes segmental bronchus.

The stump of the bronchus is now covered with adjacent pleural reflection or a free fascial graft. A rubber catheter, No. 24, is placed intercostally for drainage and continuous suction and 15 cm. of water are used for forty-eight hours to re-expand the remaining lung tissue.

Postoperatively, endotracheal aspirations are repeated as often as every hour when necessary in order to keep the tracheobronchial tree clear. Patients are ambulated at the first or second day postoperatively, which aids coughing and deep breathing. The progress of the patient is carefully observed by regular x-ray views and fluoroscopy of the chest. In an uneventful case the patient will usually feel quite well by the third or fourth day and will be ready for discharge from the hospital by the seventh to tenth day.

The complications occasionally seen are (1) atelectasis, lack of re-expansion of remaining lung tissue which can be treated by repeated bronchoscopy and insistence upon coughing; (2) fluid in the pleural space, which should be aspirated when there is a significant amount; (3) empyema, an uncommon complication, since good bronchial closure and chemotherapeutic agents usually circumvent this; (4) bronchopleural fistula, usually the result of inadequate bronchial closure, early complete re-expansion will help to eliminate this.

ANALYSIS OF CLINICAL DATA

During the year of 1947 it was found necessary to utilize the methylene blue injection method in a total of ten cases because of extreme difficulty in identifying the intersegmental cleavage plane. Nine of these cases represented segmental distribution of bronchiectasis. One patient had a giant tuberculous cavity in the left upper lobe. In all cases it was possible to accomplish the desired segmental resection, thus obviating the necessity of lobar resection. The distribution of disease in these cases was as follows: (1) Lingula, and anterior segment of left upper lobe, two cases; (2) lingula, and both anterior-medial basal and lateral basal of left lower lobe, one case; (3) lingula, and superior segment of left lower lobe, one case; (4) apical-posterior, and anterior-medial basal of left lower lobe, one case; (5) lingula alone, two cases; (6) lateral basal of left lower lobe and lateral basal and posterior basal of right lower lobe, one case; (7) superior segment of right lower lobe, two cases. Eight of these cases were uncomplicated postoperatively. Two of the patients developed empyemas which were local in character and associated with bronchopleural fistulas. Open thoracotomy and drainage of the localized empyema spaces resulted in cure in both of these complications. These two complications probably could have been avoided by a more vigorous attempt to re-expand the remaining lung tissue so as to obliterate all of the pleural space early and completely.

CONCLUSIONS

1. Segmental pulmonary resection is a surgical technique of considerable value. It is indicated in many instances and is quite feasible. Maximal good lung tissue is spared in the removal of the pathologic segments, and it is especially valuable where bilateral resection is contemplated.

2. A new technique for more adequately establishing intersegmental cleavage planes is described.

REFERENCES

1. Jackson, C. L., and Huber, J. F.: Correlated Applied Anatomy of the Bronchial Tree and Lungs With a System of Nomenclature, Dis. of Chest 9: 1-8, 1943.
2. Overholt, R. H., and Langer, L.: A New Technique for Pulmonary Segmental Resection, Surg., Gynec. & Obst. 84: 257-268, 1947.
3. Clagett, O. Theron, and Deterling, Ralph A., Jr.: Technique for Segmental Pulmonary Resection, J. THORACIC SURG. 15: 222-238, 1946.
4. Bailey, C. P.: Lung, Resection for Pulmonary Tuberculosis, J. THORACIC SURG. 16: 328-341, 1947.
5. Bailey, C. P., Tropea, F., and Rubenstein, L. H.: Recent Advances in Pulmonary Surgery, Recent Trends in Pulmonary Surgery, S. Clin. North America, December, 1947.

ENDOBRONCHIAL OCCLUSION DURING PULMONARY RESECTION

PRELIMINARY REPORT

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DURHAM, N. C.

INTEREST was aroused in the problem of controlling bronchial secretions at Duke Hospital during an analysis of 125 cases of pulmonary resection performed from 1937 to 1947; it was observed that ipsilateral and contralateral spreads had occurred in twenty-seven cases, or 21.6 per cent. In this group there were five deaths, all directly attributable to the spread. A survey of the literature revealed that our figures were not in disagreement with those of other clinics, and our methods of control of bronchial secretions were the same as those in general use.

These methods of control fall into three general categories. The first group includes preparatory measures, such as chemotherapy, postural drainage, and the postponement of operative procedures to the summer months when upper respiratory infections are at a minimum. The second group points at active control of secretions during the removal of the infected lung segment, namely, tracheobronchial aspiration by catheter, mechanical blocking of the bronchi, and positioning of the patient with dependence on gravity drainage. The third group is preventive as well as therapeutic and includes chemotherapy, deep breathing exercises, bronchoscopy, and enforced coughing.

Inasmuch as no one method will be completely successful in this problem, it is obvious that the preoperative preparatory measures of chemotherapy and enforced postural drainage must always be used, and the postoperative preventive measures should be employed routinely. Although tracheobronchial aspiration by catheter has been one of the most commonly used methods in the second group, it is not entirely satisfactory, as evidenced by our own percentage of spreads. The positioning of the patient during operation with dependence on gravity drainage of the secretions, particularly as advocated by Overholt,[1] has gone far in reducing the danger of spreads, but has not completely eradicated it.

There have been many instruments designed for mechanically blocking the various bronchi with the subsequent isolation of one or more lobes, such as the endotracheal airway described by Gale and Waters in 1931 (Fig. 1), the combined tracheoscope and anesthetic tube devised by Magill in 1936 (Fig. 2), the technique of bronchial tamponade advanced by Crafoord and described by Nosworthy in 1941 (Fig. 3), and the bronchial occluder reported by Halton in 1943 (Fig. 4). All have been described in more detail in a previous report.[2]

Since none of these instruments, in our experience, could be depended upon to perform the job for which it was designed, it was felt that an endobronchial

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balloon could be devised to obstruct the portion of lung to be removed, and to provide aspiration of air and secretions from this obstructed segment. The most obvious criticism of any instrument constructed around a balloon has been its lack of dependability, a tendency to slip out of place at inopportune times. This has been circumvented by the use of a metal holding apparatus, which fits around the balloon, and which maintains its position through the protrusion of numerous small points (Fig. 5). The instrument was first used in pulmonary resections in dogs, and it was shown that (1) no harmful effects were produced, (2) complete occlusion of the bronchus was obtained, (3) dislodgment during operation was very unlikely, (4) there was a wide margin of safety, and, (5) there was very little interference with anesthesia.[2] It was subsequently used in resections in patients, and a report was made of the results and complications during the first year.[3] Since the results appeared fairly satisfactory, the instrument has been used for another year, and the indications, effectiveness, and complications of its use are embodied in the present report.

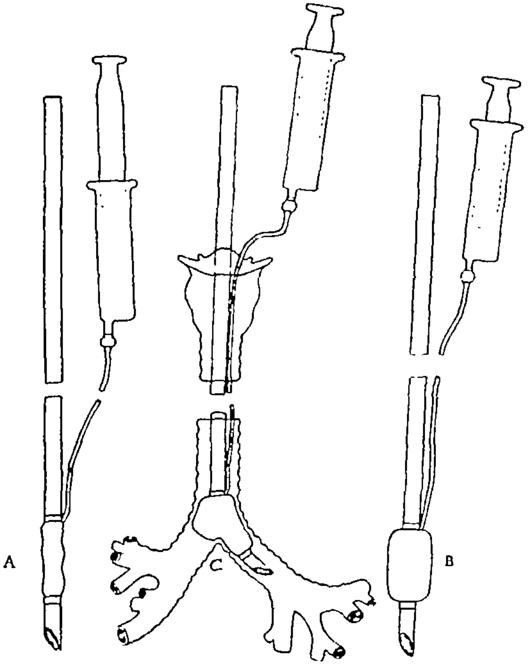

Fig. 1.—Gale and Waters endotracheal balloon with obstruction of the main bronchus at the carina.

INDICATIONS

Use of this instrument is indicated in any resection for suppurative pulmonary disease, including bronchiectasis, lung abscess, carcinoma with secondary suppuration, and tuberculosis. In its present form, it is not applicable in upper lobectomies; it is hoped that a modification of the instrument will soon be available for this particular operation. The presence of bilateral disease, particularly bronchiectasis, does not constitute a contraindication. There is ample room for suction through the endotracheal tube. On the contrary, blocking the most seriously diseased portion relieves the anesthetist of much more purulent material spilling out into the major bronchi. The balloon is particularly indicated in patients with decreased pulmonary reserve. Positive pressure anesthesia plus constant inflation of the upper lobe in cases of lower lobectomies may be maintained throughout the procedure without the hindrance to the surgeon caused by the inflation of the lobe being resected. The presence of atelectasis in the affected lobe is a definite aid to the surgeon, not only in allowing more operating space, but also in the delineation of the interlobar fissure. Although we have not as yet used the instrument in a segmental lobectomy, since the child's size is not yet available, use of this same principle in differentiation of the segments should certainly be an added advantage. In cases of tuberculosis, the presence of large amounts of hyperplastic tissue at the contemplated site of placement of the balloon constitutes a definite contraindication to the use of the instrument. This is discussed under complications further on in the report.

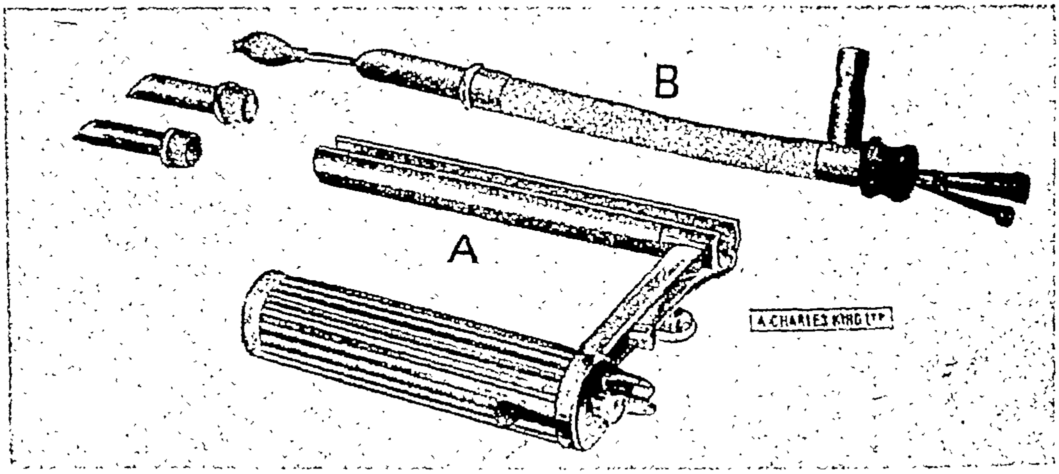

Fig. 2.—Magill's combined tracheoscope and anesthetic tube.

TECHNIQUE

During the past year very few changes have been made in the actual construction of the instrument. The carrier tube has been shortened so that the site of placement of the balloon is as close as possible to the tip of the bronchoscope. The instrument table has been discarded and the manometer and suction bottle incorporated in a metal case, thus providing a small compact unit at the operating table.

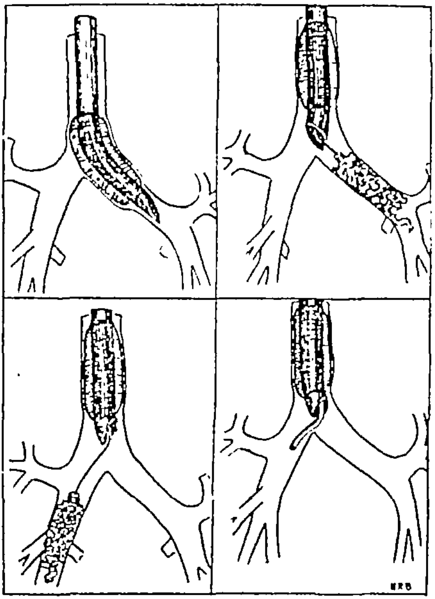

Fig. 3.—Crafoord's technique of bronchial tamponade.

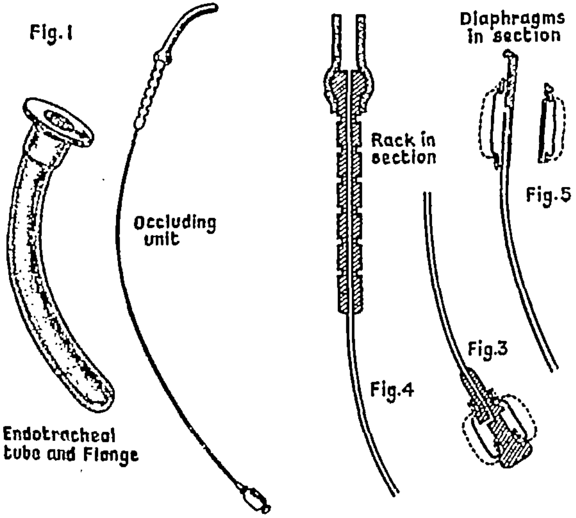

Fig. 4.—Bronchial occluding unit devised by Halton.

There have been no changes in the technique of using the instrument, save for variations in anesthesia. In approximately one-half of the cases intravenous pentothal and topical anesthesia have been used for bronchoscopy and induction; in the others, the pentothal has been used after bronchoscopy and placement of the balloon are completed. The use of pentothal for induction of general anesthesia has definitely improved the entire procedure. At the present time an average of twenty minutes is required from the beginning of topical anesthesia to the completion of placement of the balloon and beginning of general anesthesia.

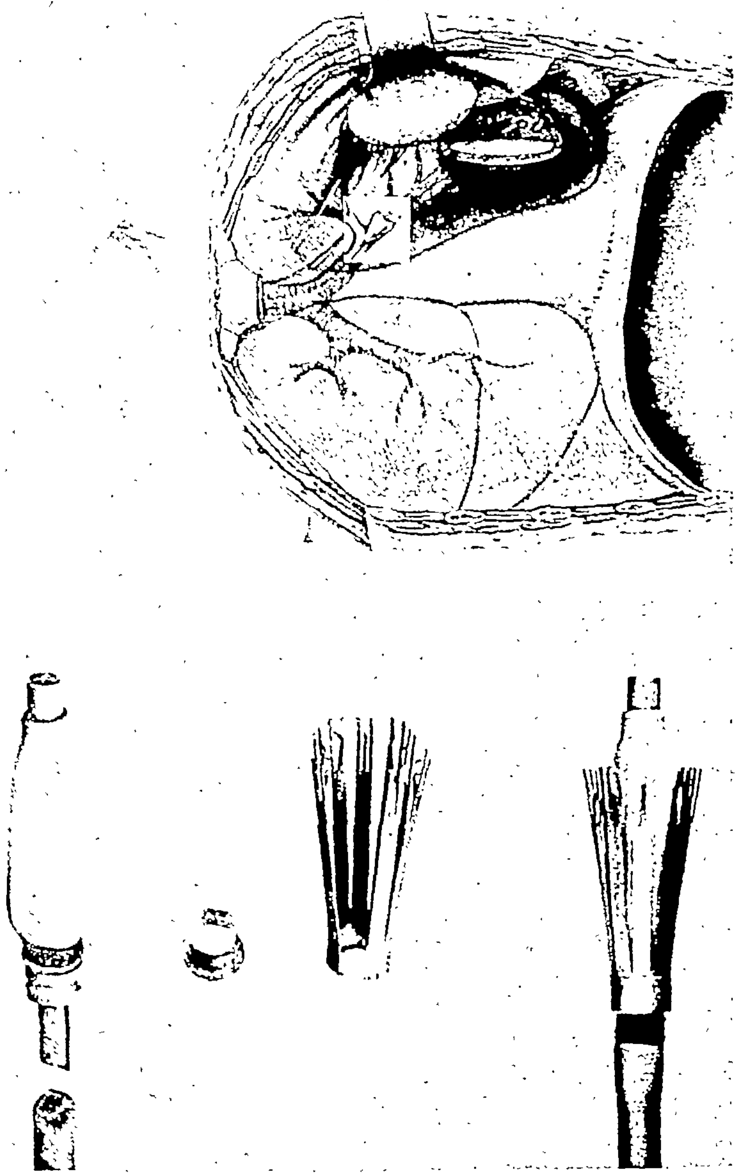

Fig. 5.—Endobronchial balloon (author's) and its diagrammatic use in a left lower lobectomy.

RESULTS

During the past twenty-four months this instrument has been used in the forty-four cases as shown in Table I.

TABLE I.

DIAGNOSIS	LOBECTOMY	PNEUMO-NECTOMY	EXPLORATORY THORACOTOMY	DRAINAGE
Bronchiectasis	15	1		
Abscess	4	2		
Bronchiogenic carcinoma		1	4	
Tuberculosis	1	14		
Foreign body	1			
Empyema				1
Totals	21	18	4	1

The empyema case was incorrectly diagnosed preoperatively as a lung abscess.

There were six deaths in this series of cases. Three of these patients died the day of operation and immediate autopsy in two revealed no evidence of spread. Autopsy was refused in the third case: death occurred very shortly after removal of the balloon and during hilar manipulation. Bronchoscopy at the time of death revealed the bronchi on the unaffected side to be free of secretions. The other three deaths occurred at sixteen, twenty-three, and forty-two days, respectively, of secondary postoperative complications. Two of the cases had no evidence of spread clinically or by repeated chest x-ray examinations. The third had a definite fatal contralateral infection and is discussed under "spreads."

In thirty-three of the forty-four cases, the instrument functioned satisfactorily as judged by complete bronchial occlusion, the production of atelectasis in the obstructed lobe or lobes, and the lack of a postoperative spread. Anesthesia has been definitely improved and, in general, the postoperative course of these patients has been smoother.

Spreads.—There were six cases in which contralateral spread occurred. One proved fatal, one was moderately severe, and the other four were all minimal.

The most severe spread occurred in a left pneumonectomy for tuberculosis; immediate postoperative x-ray views were clear, but on the fourth day, infiltration appeared in the right lower lobe and gradually progressed to involve the entire right lung, resulting in death forty-two days postoperatively. Although preoperative roentgenograms showed only diffuse scarring throughout the right lung, this might possibly be classified as a reactivation rather than a postoperative spread; the instrument functioned perfectly throughout the operation.

In one patient with multiple lung abscesses, it was felt that all cavitation was confined to the middle and lower lobes, and the balloon was inserted for a middle and lower lobectomy. The resulting contralateral spread from a cavity in the unobstructed upper lobe was moderately severe, but was relieved by bronchoscopy following the operation.

Of the four minimal spreads, two occurred in cases of tuberculosis, and there is no adequate explanation as to their cause. In the third case, a pneumonectomy for carcinoma, the instrument became lodged in a sharply curved endotracheal tube on removal, and several seconds elapsed before the bronchus was clamped. Sufficient spillage of secretions could have occurred to account for the small spread. In the last case, an abscess in the superior segment of the left lower lobe, the balloon was placed too low, and the superior branch bronchus was not obstructed.

Thus, of the six instances of spread, there is an explanation for three; the remaining three were all cases of tuberculosis.

Mechanical Complications.—Complications due to mistakes in technique occurred in five cases without evidence of postoperative spread. In two, the balloon was placed in the right main bronchus for a right pneumonectomy. Due to the extreme shortness of the right main bronchus, and because the balloon was placed too close to the carina, there was overdistention into the trachea with resultant partial obstruction, and it was necessary to remove the balloon. There were two left pneumonectomies for tuberculosis, in both of which there was extensive hyperplastic tissue filling the left main bronchus. It was realized that the balloon would probably not be retained in this hyperplastic tissue, but the presence of large amounts of purulent material in the stenosed lung necessitated its use. In each case, the balloon slipped out into the trachea during manipulation of the lung; tracheal obstruction was only momentary and was immediately relieved. No complications arose in the one case, but in the other, after removal of the balloon, the patient had sudden cardiac arrest during hilar manipulation and quickly died. An autopsy could not be obtained. The fifth and last case concerned an abscess in the superior segment of the right lower lobe; the balloon was placed too low, as denoted by the atelectatic basilar segments and inflated superior segment. The resulting spillage was removed by repeated tracheobronchial aspiration; fortunately a spread did not occur.

COMMENTS

Judging from the results up to the present time, certain conclusions can be drawn. The results in all types of cases are comparable except for tuberculosis. By improving the technique of handling the instrument and thus eliminating the complications which have occurred in this series, it is felt that the danger of spread in bronchiectasis, abscess, and bronchiogenic carcinoma with secondary suppuration may well be minimized.

The three unexplained spreads occurred in cases of tuberculosis, and were part of a group of six patients in whom streptomycin was not used. In the remaining nine cases, streptomycin was used both pre- and postoperatively, and spread did not occur. A much larger series of cases may afford some clue as to the mode of spread in tuberculosis.

In regard to the site of placement of the balloon in the bronchial tree, satisfactory positioning for lower lobectomy on either side, for resection of the middle and lower lobes on the right, and for pneumonectomy on the left is relatively simple. It is somewhat more difficult to block the superior branch bronchus of the lower lobes, as evidenced by failure in two of the twenty-one lobectomies.

Blocking the entire right main bronchus between the upper lobe orifice and the main carina is considerably harder, and should not be attempted without experience with the instrument. Placement of the balloon in two of the six right pneumonectomies was unsuccessful.

Experience with the instrument has shown that attention to the following details will decrease the chance of failure. Enforced postural drainage just prior to bronchoscopy has obviously facilitated this procedure. It is wise to institute suction through the balloon as soon after placement as possible, otherwise thick secretions may obstruct the aspirating tip before atelectasis is obtained. On removing the balloon the bronchus should be clamped as quickly as possible to prevent any spillage of dammed-up purulent material. Furthermore, thorough tracheobronchial suction should be carried out at the same time to catch any material which might spill out.

SUMMARY

An instrument designed for endobronchial occlusion and the results of its use in the first forty-four cases of resection for suppurative pulmonary diseases are reported. The results are sufficiently encouraging to warrant further clinical trial.

REFERENCES

1. Overholt, Richard H., Langer, L., Szypulski, J. T., and Wilson, N. J.: Pulmonary Resection in the Treatment of Pulmonary Tuberculosis, J. THORACIC SURG. 15: 384, 1946.
2. Moody, James D., Trent, J. C., and Newton, G. W.: An Endobronchial Balloon for the Control of Bronchial Secretions During Lobectomy and Pneumonectomy, J. THORACIC SURG. 16: 258-261, 1947.
3. Moody, James D.: A Method of Bronchial Occlusion for the Prevention of Transbronchial Spread During Lobectomy and Pneumonectomy; Clinical Application, J. THORACIC SURG. 17: 681-689, 1948.

DISCUSSION

DR. J. C. TRENT, Durham, N. C.—I should like to thank Dr. Moody for a very ingenious bit of work and an excellent presentation of this problem today. The instrument has been in use in Duke Hospital for the past two years and I can say that it does work. Complete occlusion of the bronchus can be produced, the balloon remains in place and will retain secretions, and in addition does produce atelectasis as shown in the movie. This greatly simplifies the surgeon's job. The upper lobe may be inflated, the dissection of the hilum is simplified, the postoperative course is smoother, and I think the addition of the use of this balloon for bronchial obstruction will improve the clinical results, especially when used in combination with streptomycin in tuberculosis.

DR. MOODY.—I should like to make sure that it is clear that this instrument is not applicable in upper lobectomies. It has been designed for lower lobectomies or pneumonectomies. The instrument designed for an upper lobectomy has not yet been completed.

I am particularly gratified to learn of the results achieved with streptomycin. We are becoming much more cognizant of the fact that contralateral spread does not always occur by way of the transbronchial rote. We have occluded the main bronchus in a number of cases of tuberculosis and several controlateral spreads have developed in spite of the fact that the instrument was functioning satisfactorily throughout the operative procedure.

MEDULLARY PEGGING IN THORACOTOMY INCISIONS

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THE prerequisite of a good thoracotomy incision is adequate exposure not only of the immediate intrathoracic operative area, but also of the entire pleural space, which is particularly important in the presence of pleural adhesions. Good visualization of the entire intrathoracic structures and a large enough thoracotomy opening to allow free surgical manipulation are essential for a safe and rapid operative procedure. Equally important requirements of a thoracotomy incision are ease of closure with the production of a pain-free, stable hemithorax permitting full respiratory movement, minimal disturbance in the function of the shoulder, and, last but also important, good cosmetic results. The position of the patient on the operating table during the surgical procedure should also be considered and should not interfere with maximum function of the contralateral lung.

With the exception of inadequate exposure for certain posterior mediastinal lesions, the anterolateral incision as originally used by Rienhoff[1] meets most of the requirements of a good thoracotomy. The supine position interferes very little with the respiratory movement of the contralateral thorax and flooding of this lung can be prevented by frequent tracheal aspiration. The submammary incision will give excellent cosmetic results and section of the pectoralis major at its insertion will produce minimal damage to this muscle and its nerve. In young patients a third intercostal incision alone carried to the posterior axillary line will give excellent exposure with the use of a good spreading rib retractor. In older individuals the intercostal incision is usually combined with section of the costal cartilages of the third and fourth ribs. Overspreading of the rib retractor will lead to fractures of the adjacent ribs and for this reason when a larger thoracotomy is desired, additional cartilages should be sectioned. The repair of an anterior intercostal incision can be accomplished without difficulty by first approximating and suturing the sectioned costal cartilages. For airtight closure, if necessary, the pectoralis major muscle can be used for reinforcement of the intercostal suture line. Resection of a rib in an anterior thoracotomy is not advisable since this will make closure of the incision quite difficult due to the marked thinness of the anterior portion of the intercostal muscles. The anterior thoracotomy incision without resection of a rib will produce a stable thorax with minimal disturbance in respiratory movement. Postoperative pain is prevented by novocain injection or crushing of the third or adjacent intercostal nerves.

The posterolateral incision as first used by Lilienthal[2] is preferred by many to the anterior incision. This incision when used with either a high or low

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intercostal thoracotomy will give access to the upper or lower portion of the thorax as well as to the posterior and anterior mediastinum. It is particularly adapted for surgery on the esophagus, the vagus and sympathetic nerves, and the diaphragm. The lateral position of the patient on the operating table in this type of thoracotomy will somewhat interfere with respiratory movement of the contralateral hemithorax, unless shoulder and pelvic supports are used. A special table has been devised by Overholt[3] to overcome this difficulty. Preoperative use of antibiotics parenterally and by aerosol together with bronchoscopic aspiration has greatly reduced the hazards of contralateral lung flooding during resection of suppurative lung lesions. However, frequent tracheal aspiration during the operation and the Trendelenburg position will minimize this danger.

The skin incision is made starting at the level of the third or fourth rib, midway between the spine and the vertebral border of the scapula, and carried downward encircling the tip of the scapula and continuing along the seventh or eighth interspace to the anterior axillary line. The trapezius and rhomboideus muscles are cut close to the spine while the latissimus dorsi and serratus anterior are sectioned at least 6 cm. inferior to the tip of the scapula. Section of these muscles close to their insertion will produce minimal interference with postoperative movement of the shoulder.

Identification of the ribs in the posterolateral incision is greatly simplified by elevating the scapula and counting the ribs from above downward, the first rib being easily identified by its flatness and sharp ridge of the inferior border. The attachment of the posterior scalenus muscle to the second rib identifies this structure. For operations in the upper thorax the thoracotomy is accomplished through an intercostal incision in the fourth or fifth interspace, while for lower lobectomy and operations on the lower esophagus and diaphragm the incision can be made in the eighth or ninth interspace. An intercostal incision without section or resection of ribs, if carried forward anteriorly to the costal cartilage, frequently will give adequate exposure in young individuals. However, in older individuals and also in patients with marked thickening of the parietal pleura, the intercostal incision alone will not give sufficient exposure and overspreading of the rib retractor often will lead to fracture of ribs. The advantages of an intercostal incision without rib section are that it will allow easy closure of the thoracotomy, and deformity as such is absent. With crushing of one intercostal nerve, postoperative pain will be minimal and there will be very little interference with normal respiratory movements.

Resection of the major portion of a rib from its angle to the anterior axillary line or the costal cartilage with an incision through the periosteal bed is frequently used in the posterolateral thoracotomy. The exposure resulting from such thoracotomy may be inadequate in older individuals, in patients with thickened pleura, and in operations upon the esophagus. The removal of one rib creates a definite depression deformity which is particularly evident when used in the lower thorax. Closure of such thoracotomy is facilitated by the presence of the fascia-like structure of the periosteum of the resected rib;

however, considerable force is necessary to approximate the edges of this incision. With paralysis of the two adjacent intercostal nerves by novocain injection or crushing, there is minimal interference with respiratory movement.

An intercostal incision combined with section of two or more adjacent ribs will produce adequate exposure for all intrathoracic operations. However, on closure of this thoracotomy considerable difficulty is experienced in approximating the sectioned intercostal muscles requiring the use of sutures encircling the two adjacent ribs.[4, 5] Unless these sutures are placed subperiosteally, postoperative pain may occur due to pressure of the suture on the intercostal nerve of the inferior rib. Immobilization and accurate approximation of the cut ribs cannot be obtained by suture of the intercostal muscles to the longissimus dorsi and iliocostalis muscles. Blades and Kent[6] advised the use of sutures placed through drill holes of the ends of the sectioned ribs. Unless the cut rib ends are approximated accurately and held in place firmly, the negative intrathoracic pressure will produce overriding of the rib fragments and the anterior rib segment is displaced posteriorly for a considerable distance, resulting in a thoracic depression deformity of considerable magnitude, particularly when two or more ribs are involved (Fig. 1). Constant movement of the rib ends and overriding with impingement of the intercostal nerves leads to considerable postoperative pain, particularly when nonunion of the sectioned ribs occurs. Crushing of the intercostal nerves, and particularly Novocain injection, will not be effective since union of the ribs does not occur for several months and may not occur at all. Irregular union with excessive callus formation greatly contributes to late postoperative pain (Fig. 2).

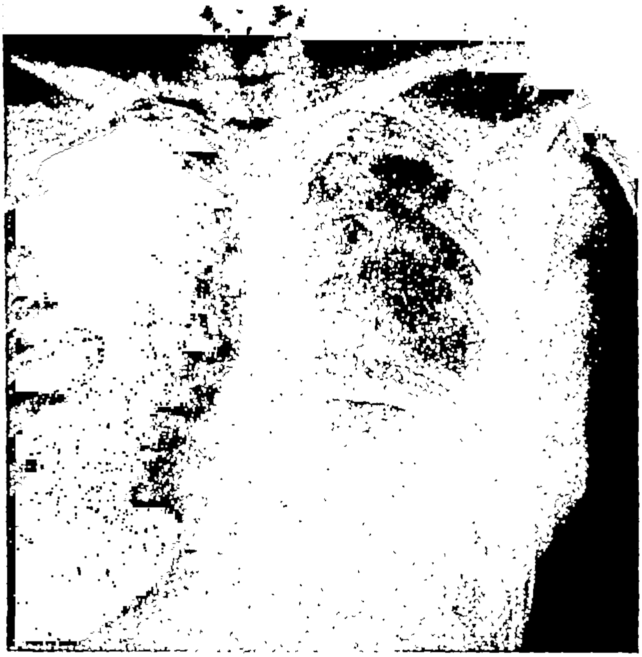


Fig. 1.—Thoracic deformity and excessive callus formation due to failure of accurate approximation of the sectioned rib fragments.

The prerequisite of a good thoracotomy incision has been met in this series in fifty patients by the use of the posterolateral intercostal incision and autogenous medullary pegging of the adjacent sectioned ribs. The exposure was adequate in all cases and suture of the intercostal muscles was accomplished with ease, without the use of a rib approximator or rib encircling sutures. There was minimal interference with respiratory movement of the thorax and deformities did not occur. Early unrestricted shoulder movement was possible and the cosmetic results were good. There was minimal postoperative pain, requiring only occasional use of narcotics. Ambulation on the first postoperative day was the rule and the postoperative hospital stay was short. The average hospital stay in twenty-four patients following lobectomy for bronchiectasis, decortication, and removal of mediastinal tumors was eight days. No atelectasis occurred.

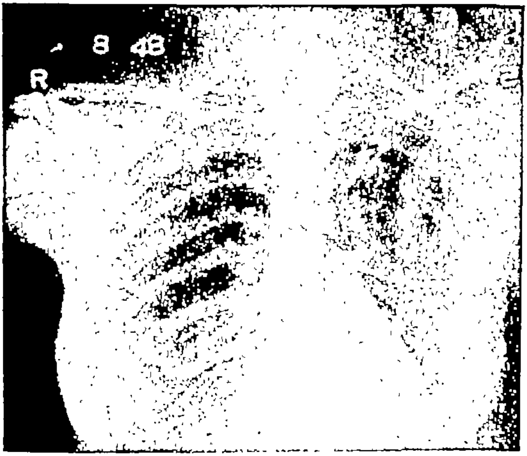
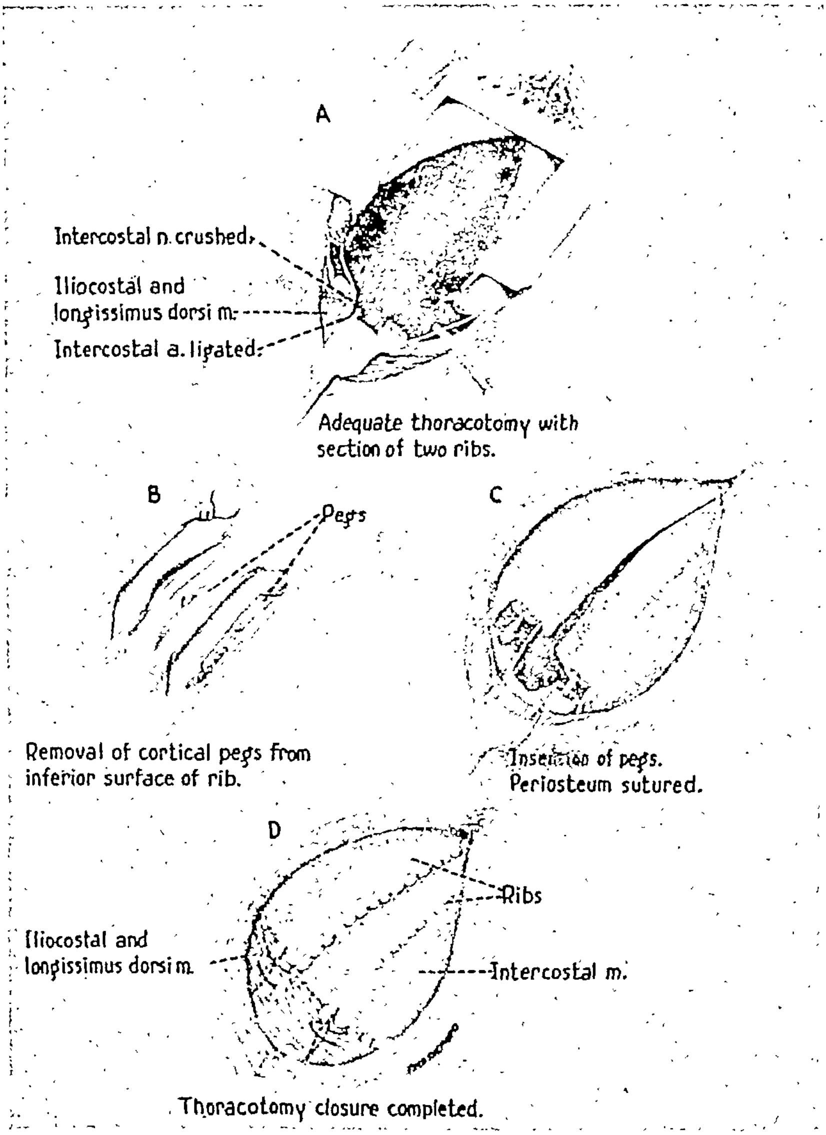


Fig. 2.—Overriding of the sectioned rib fragment and failure of regeneration of the resected rib with marked lateral thoracic deformity.

The usual posterolateral skin incision is used with section of the extrathoracic muscles close to their insertion. The longissimus dorsi and iliocostalis muscles are stripped from the ribs adjacent to the intercostal incision down to the transverse processes and retracted medially. A 1 cm. area of the periosteum is stripped from the two adjacent ribs 2 cm. distal to the transverse processes and the two ribs are transected without the removal of a segment (Fig. 3). The intercostal nerves of the corresponding ribs are exposed and crushed or injected with Novocain. The intercostal vessels above the intercostal incision are ligated with transfixation sutures and cut. Transection of two ribs usually gives excellent exposure; however, more can be cut should a wider exposure be desirable. On completion of the intrathoracic operation a 4 cm. long, 4 mm.

wide diamond-shaped section of the inferior border of the lateral portion of the rib above or below the intercostal incision is resected subperiosteally. The periosteum of this area is closed with interrupted fine silk. The removed section of rib is cut diagonally into two 3 cm. long, pointed cortical bone pegs which are inserted into the medullary cavity of the proximal rib stumps. On approximating the anterior rib segment to the proximal stump the sharp protruding peg will enter the medullary cavity and lock the rib in place (Figs. 4 and 5). The longissimus dorsi and iliocostalis muscles are next sutured to the intercostal muscles and for additional stability a suture may be placed encircling the distal portion of the rib firmly holding it in place. The intercostal muscles are next approximated by using interrupted sutures of fine silk. The cut segments of



Adequate thoracotomy with section of two ribs.

Removal of cortical pegs from inferior surface of rib.

Insertion of pegs. Periosteum sutured.

Thoracotomy closure completed.

Fig. 3.—Technique of medullary pegging of ribs in thoracotomy.

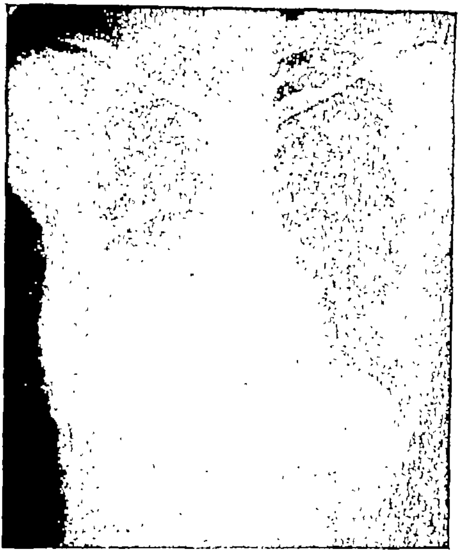


Fig. 4.—Immediate postoperative position of the sectioned ribs.

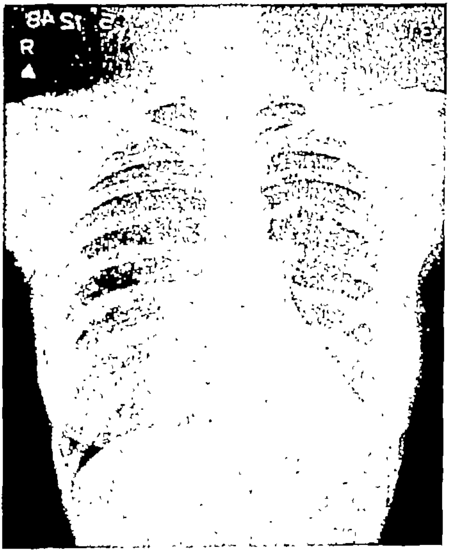


Fig. 5.—Bony union of the rib segments with minimal callus formation.

TABLE I. INTRATHORACIC OPERATIVE PROCEDURES USING MEDULLARY PEGGING OF RIBS

Lobectomies	24*
Pneumonectomies	6
Decortication	6†
Removal of mediastinal tumors	5‡
Exploratory thoracotomy	4
Esophageal operations	3
Patent ductus section	1
Closure of bronchial fistula	1
Total number of cases	50

*Two failures due to fracture of one peg.
†One failure due to fracture of one peg.
‡One failure, pegs too short.

the extrathoracic muscles are carefully approximated and sutured with interrupted silk. Interrupted silk is used for the skin.

In fifty thoracotomies performed for various surgical procedures as shown in Table I there were failures in four instances. In one patient with extensive carcinomatosis the ribs were extremely soft and an adequate bone peg could not be obtained. In one patient early in this series the pegs were too short and both ribs became disengaged. In two patients there was fracture of one peg each occurring on the first postoperative day.

SUMMARY

Adequate exposure for intrathoracic operations using the posterolateral incision has been obtained by the use of an intercostal thoracotomy combined with section of the two adjacent ribs. The use of autogenous medullary rib pegs has greatly facilitated closure of the intercostal incision with the production of a pain-free, stable thorax.

REFERENCES

1. Rienhoff, W. F.: The Surgical Technic of Total Pneumonectomy, Arch. Surg. 32: 218, 1936.
2. Lilienthal, H.: Thoracic Surgery, Philadelphia, 1925, W. B. Saunders Company.
3. Overholt, R. H., Langer, L., Szypulski, J. T., and Wilson, N. J.: Pulmonary Resection in the Treatment of Tuberculosis, J. THORACIC SURG. 15: 384, 1946.
4. Garlock, J. H.: The Surgical Treatment of Carcinoma of the Esophagus, Surg., Gynec. & Obst. 70: 556, 1940.
5. Janes, R. M.: Total and Partial Pneumonectomy in the Treatment of Pulmonary Tuberculosis, J. THORACIC SURG. 14: 3, 1945.
6. Blades, B., and Kent, E. M.: Individual Ligation Technique for Lower Lobe Lobectomy, J. THORACIC SURG. 10: 84, 1940.

OBSTRUCTIVE PNEUMONITIS OF NEOPLASTIC ORIGIN

An Interpretation of One Form of So-called Atelectasis and Its Correlation According to Presence or Absence of Sputum

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THE increasing safety with which it is possible to remove a lung surgically has led to a heightened demand for more frequent and more nearly accurate preoperative diagnosis of cancer. Although the cytologic examination of sputum was well described by Dudgeon and Wrigley[1] in 1935, it was not widely accepted at that time. Until recent years, the cytologic diagnosis of carcinoma of the lung on the basis of examination of sputum and bronchial secretions was largely a curiosity, and there was little to be accomplished surgically once the diagnosis was made. Largely as a result of the changed attitude toward pulmonary surgery, there has been a rebirth of interest in the cytologic examination of sputum and bronchial secretions, with the general hope that cancer of the lung may be detected more frequently and earlier.

Our experience with cytologic examination of sputum and bronchial secretions has indicated that examination of one or the other of these materials alone is not adequate. We have conducted cytologic examinations of approximately 2,400 specimens of sputum and bronchial secretions, the vast majority of which have been specimens of sputum. In this group we have at present 225 positive results among individual patients. Some of these represent positive results concerning sputum alone, some represent positive results concerning secretions alone, but in the vast majority of instances, it was possible to obtain positive results concerning both sputum and secretions. Cytologic examination of sputum is further indicated because of its value in the detection of cancer of the lung. Our conclusions in respect to this method have been that examination of both secretions and sputum should be done. With this in mind, it becomes exceedingly important to know the factors responsible for the production of sputum.

NATURE OF STUDY

The value of cytologic examination of bronchial material in the diagnosis of cancer of the lung has been aptly demonstrated. We felt, therefore, that it was important to determine those factors which are responsible for the production of sputum and how early sputum was produced in a group of patients who had proved cancer of the lung.

We have, therefore, re-examined all the lungs or lobes of lungs removed because of a neoplasm at the Mayo Clinic from May 6, 1935, to July 1, 1947.

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Three groups of pulmonary neoplasm were excluded from this study: (1) hamartomas (which in our experience have not produced sputum), (2) endobronchial lipomas and similar lesions, and (3) carcinomatous bronchial cysts.

The examination included a careful gross inspection of not only the neoplasm but also of the nonneoplastic portion of the lung. Blocks were taken from both the neoplasm and the pulmonary tissue of the affected segment of the lung. Sections were cut from these blocks and hematoxylin and eosin stains were used. Special stains, particularly van Gieson, were used when indicated.

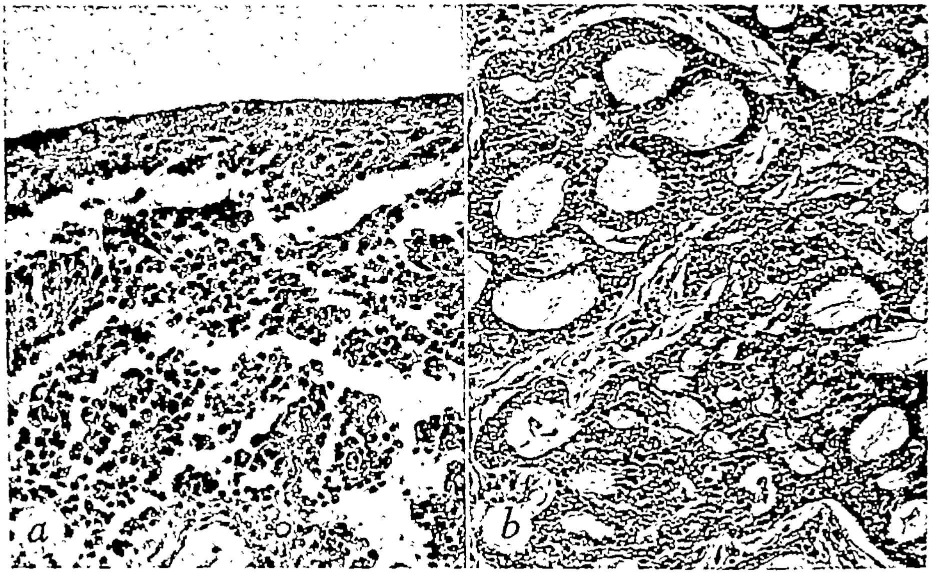

Fig. 1.—*a* (Case 27). Carcinoid type of adenoma of the left main bronchus: notice the intact benign epithelium overlying the tumor (×150); *b*, cylindroma type of adenoma in Case 23, from the left main bronchus: the Swiss-cheese pattern is apparent (×150). (Hematoxylin and eosin stain.)

All the tumors were classified into four groups: (1) adenoma of the carcinoid (Fig. 1, *a*) or cylindroma type (Fig. 1, *b*), (2) bronchiogenic carcinoma, (3) metastatic neoplasm, and (4) alveolar cell carcinoma. The bronchiogenic carcinomas were further classified into their cellular types: (1) squamous cell type (Figs. 2, *a* and *b*, and 3, *a*), in which the presence of keratinization, pearly bodies, or prickle cells was necessary, (2) undifferentiated large cell type, in which the cell type is large but there is no evidence of differentiation to squamous carcinoma or adenocarcinoma, (3) adenocarcinoma type, in which the neoplastic cells form mucus or acini, and (4) small or oat cell type (Fig. 3, *b*), in which the cells are small, round, or oval and contain little cytoplasm, and in which the nuclei have insignificant nucleoli.

The pneumonitis was graded according to a combination of the severity suggested by the microscopic picture as well as the gross extent of the process. Grade 1 pneumonitis indicates slight early pneumonitis, with very little areal involvement of the pulmonary tissue (Fig. 4, *a*) and grade 4 indicates very late, severe pneumonitis often involving a great extent of the lung (Figs. 4, *b* and 5, *a* and *b*). Grade 2 pneumonitis (Fig. 6, *a*) and grade 3 pneumonitis are

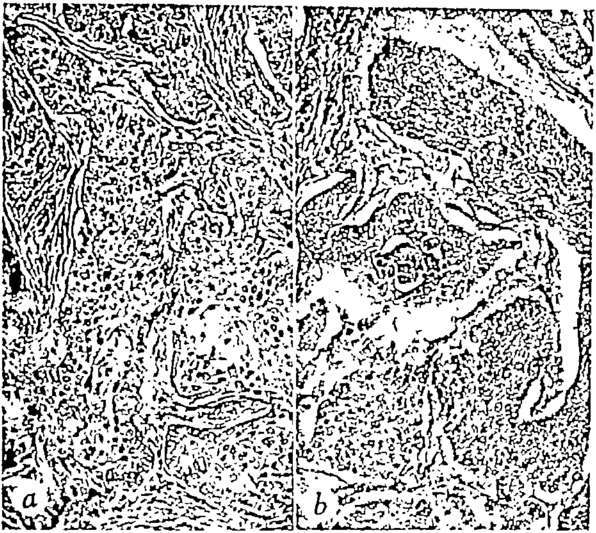

Fig. 2.—*a* (Case 65). Squamous cell type of bronchiogenic carcinoma of the main lower lobe bronchus (×15) ; *b*, squamous cell type of bronchiogenic carcinoma of the right lower lobe bronchus in Case 99 (×150). (Hematoxylin and eosin stain.)

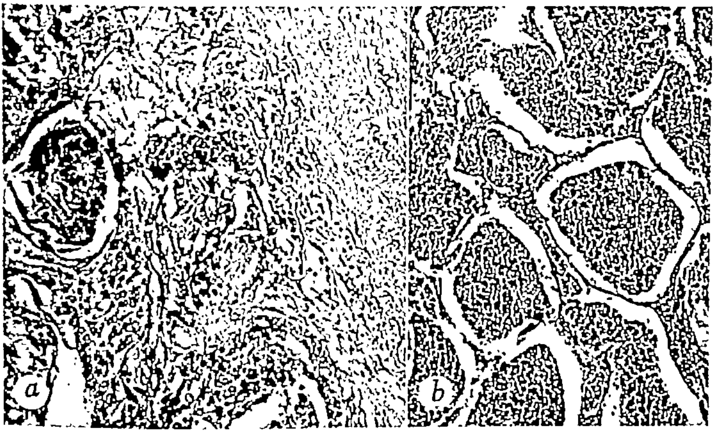

Fig. 3.—*a* (Case 62), Squamous cell type of bronchiogenic carcinoma of the right lower lobe bronchus, showing marked necrosis which is evidenced by the loss of all cellular detail; the voluminous amount of sputum raised by this patient (Table IV) was the result of evacuation of this necrotic material into the bronchial tree (×150); *b*, small or oat cell type of bronchiogenic carcinoma of the upper left lobe bronchus in Case 171: the cells are small, round, or slightly elongated, and stain very deeply (×150). (Hematoxylin and eosin stain.)

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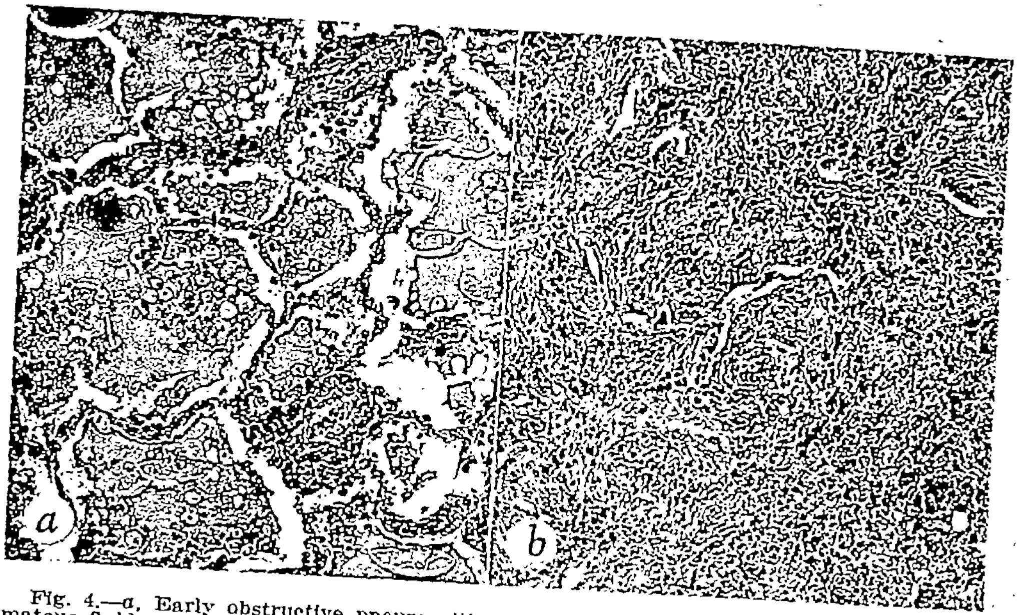

Fig. 4.—*a*, Early obstructive pneumonitis, in which the pulmonary alveoli are filled with edematous fluid; some polymorphonuclear leucocytes, lymphocytes, and phagocytes are present in the interalveolar septa and in the alveoli: this is an example of pneumonitis of grade 1 (×100); *b*, obstructive pneumonitis in the peripheral portion of the lung in Case 27 (see Fig. 1, *a*); notice the very marked fibrosis and the disappearance of the alveoli: this is an example of pneumonitis of grade 4 (×100). (Hematoxylin and eosin stain.)

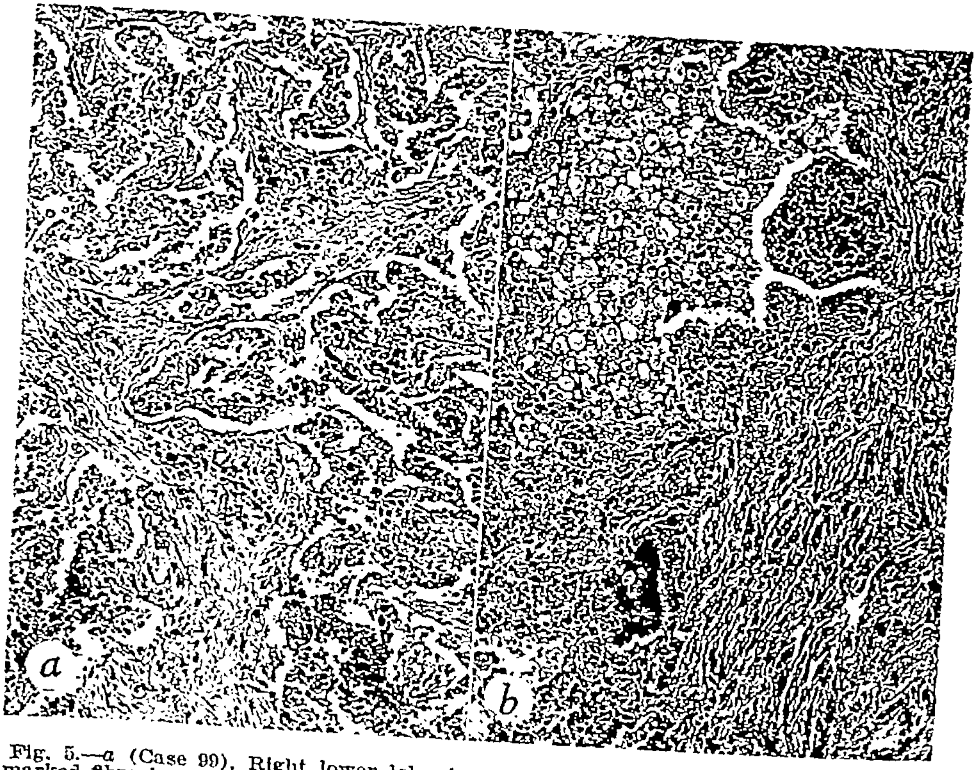

Fig. 5.—*a* (Case 99), Right lower lobe (see Fig. 2, *b*), showing pneumonitis of grade 4, with marked fibrosis and disappearance of the alveolar structure: notice the inflammatory cells (×100); *b*, section from the left upper lobe in Case 171 (see Fig. 3, *b*), showing pneumonitis of grade 4, with marked fibrosis: some fat-filled phagocytes are apparent, but no pulmonary alveoli can be seen (×100). (Hematoxylin and eosin stain.)

intermediate stages. In grade 1 pneumonitis it was possible to recognize the pulmonary alveoli; in grade 4 pneumonitis it was impossible to do so.

The records of these patients then were reviewed independently of the results of the gross and histologic examinations. Particular attention was accorded the presence or absence of sputum and, if sputum was present, the amount. The sputum was graded according to the volume. Hence, when very little (less than 1 ounce in twenty-four hours) was present, the sputum was graded 1; when 1 to 2 ounces in twenty-four hours was present, the grade was 2; when 2 to 3 ounces in twenty-four hours was present, the grade was 3; and when more than 4 ounces in twenty-four hours was present, the grade was 4.

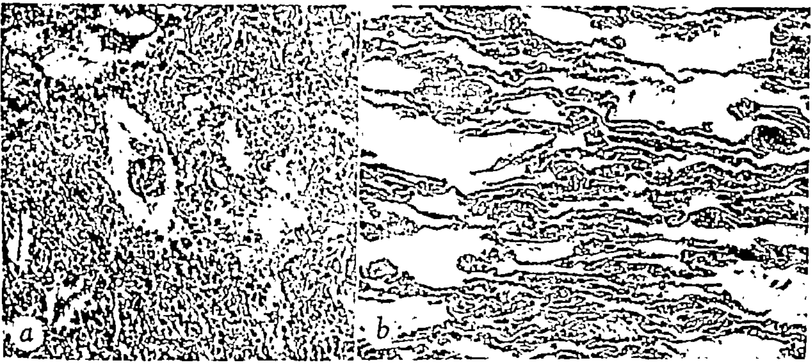

Fig. 6.—*a* (Case 23). Pneumonitis of grade 2 in the upper lobe; there is definite fibrosis, but a few remaining pulmonary alveoli can be seen (×100); *b*, section of atelectatic tissue in a case of hydrothorax: notice collapse of the pulmonary alveoli and the absence of any inflammatory reaction (×100). (Hematoxylin and eosin stain.)

DEFINITION OF TERMS

It became evident in this investigation that the lesion situated in the peripheral portion of the lung which drained into the affected bronchus was the factor which most frequently produced sputum. This is the lesion which roentgenologists in particular refer to as "atelectasis." Atelectasis is defined in Dorland's *American Illustrated Medical Dictionary* as either an "imperfect expansion of the lungs at birth," or as "partial collapse of the lung." The word derives from two Greek words meaning "imperfect expansion."

In medical literature, there are four different types of conditions in the lung which are referred to as "atelectasis." The one most acceptable is fetal atelectasis, in which there is failure of the lungs to expand at birth. The second type is the condition in which the lung is collapsed as a result of external pressure, such as hydrothorax (Fig. 6, *b*). The third is the condition known as "postoperative atelectasis," the histopathologic aspects of which are inadequately described because material is seldom available in the acute phase. The fourth is the condition under discussion herein, in which the lung becomes airless and becomes contracted after obstruction to the bronchus from varying causes, the main cause being, however, an obstructing neoplasm in the bronchus.

Since it appears to us that the genesis of these four conditions is different, we should like to abandon use of the term "atelectasis," at least as it refers to the peripheral pulmonary changes associated with obstructive lesions of the bronchus. As an alternative, we would suggest the term "obstructive pneumonitis." This would appear to be a better term for this condition than such terms as have been applied, in addition to "atelectasis." Such terms as "organizing bronchopneumonia," or "chronic interstitial pneumonia," "bronchiectasis," and "chronic indurative pneumonia," in our opinion, describe only part of the entire syndrome which we think should be designated as "obstructive pneumonitis."

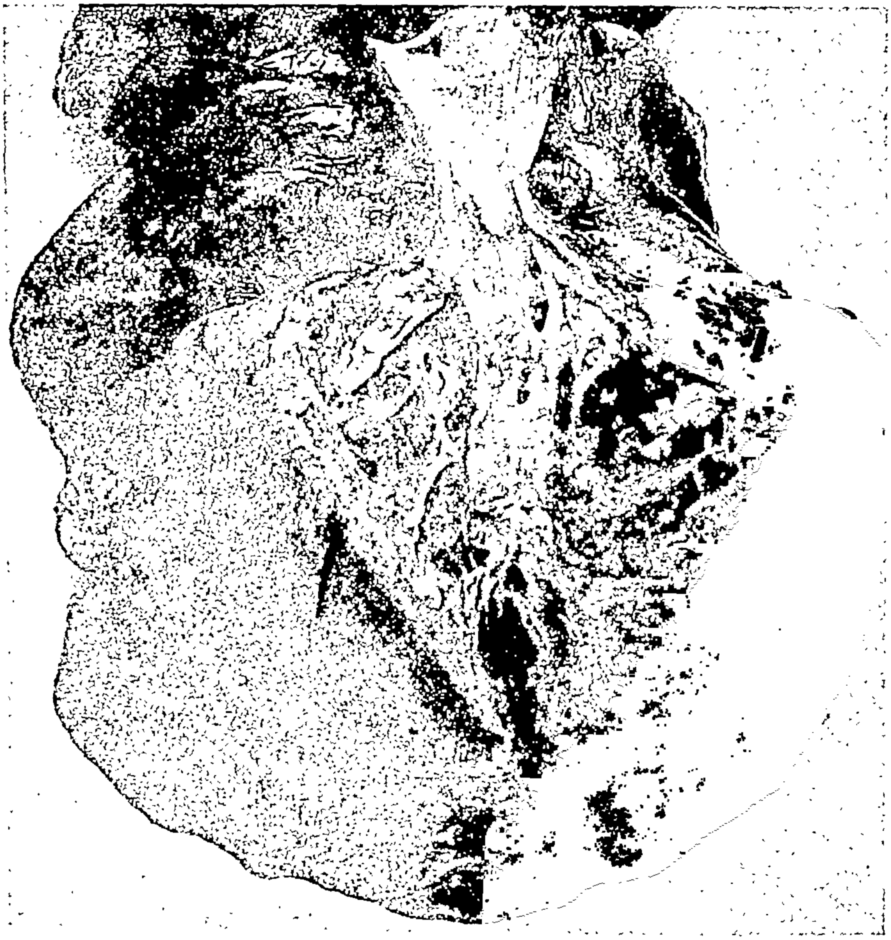

Fig. 7.—Bronchiogenic carcinoma, squamous cell type, of the lower lobe bronchus. The obstructive jaundice in the lower lobe is evident. The bronchi are widely dilated, and contain secretions. The lobe has not contracted. This represents an early stage of obstructive pneumonitis.

GENESIS OF OBSTRUCTIVE PNEUMONITIS OF NEOPLASTIC ORIGIN

We should like to depict the various stages in the genesis of this condition when the cause of the obstruction is a neoplasm. In the early stages, the obstructive lesion produces a damming-back of secretions into the bronchi and even into the alveoli. In this stage the involved portion of lung usually is reddish. The bronchi are dilated and filled with mucus, and the alveoli are filled with mucus and serum. The serum apparently is an exudate from the capillaries. In this stage, there is no contraction of the involved portion of the lung (Fig. 7). Rather, it is more voluminous than normal. However, in this and subsequent stages the involved lobe or lung is airless. This condition has sometimes been referred to as "drowned lung." Inflammatory cells in the form of polymorphonuclear leucocytes, plasma cells, and lymphocytes can be found in this stage in the affected pulmonary tissue. In this and later stages it is frequently possible to demonstrate bacterial organisms. As the lesion progresses, it is often possible, moreover, to find areas of lipoid-filled phagocytes in the pneumonitic area. In a short time organization of the exudate ensues, which in several weeks leads to the formation of collagen which becomes more marked as the time interval increases.

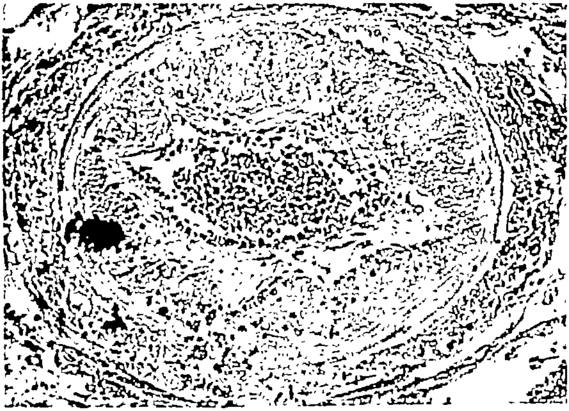

Fig. 8 (Case 88).—Pulmonary arteriole in a section of lung, showing advanced obstructive pneumonitis. Notice the marked intimal thickening with resulting narrowing of the lumen (hematoxylin and eosin, X200).

The affected lung in the stage in which fibrosis is present shows remarkable changes in the pulmonary arteries and veins, particularly those of medium size and smaller ones. As the process progresses, endarteritis (Fig. 8) affects both the pulmonary arteries and veins in the lobe or lung. This may progress to complete occlusion of the vessel. The process apparently is only an expression of the lack of function of the lobe, with the diminished need for blood. This condition might well be called "physiologic endarteritis." It occurs in the vessels to any organ which ceases to function.[2] One of the best examples outside the lung is the kidney.

In the lung, this condition of course leads to contracture of the lobe (Fig. 9). Grossly, the affected lobe in this stage is firm, and brownish or gray, with thickening of the overlying visceral pleura. Less commonly, the pneumonitis progresses to formation of abscesses (Fig. 10). When abscesses form, they are no different from other pulmonary abscesses. They may break through to the pleura and lead to empyema, with bronchopleural fistula. Since the neoplasm which is the cause of the bronchial obstruction is not static, there are bronchi which have been obstructed more recently than others. As a result, there is considerable variation in the age of the pneumonitic process. We believe that it is the mucopurulent fluid accompanying pneumonitis which forms most of the sputum in the majority of patients who have neoplasms of the bronchus.

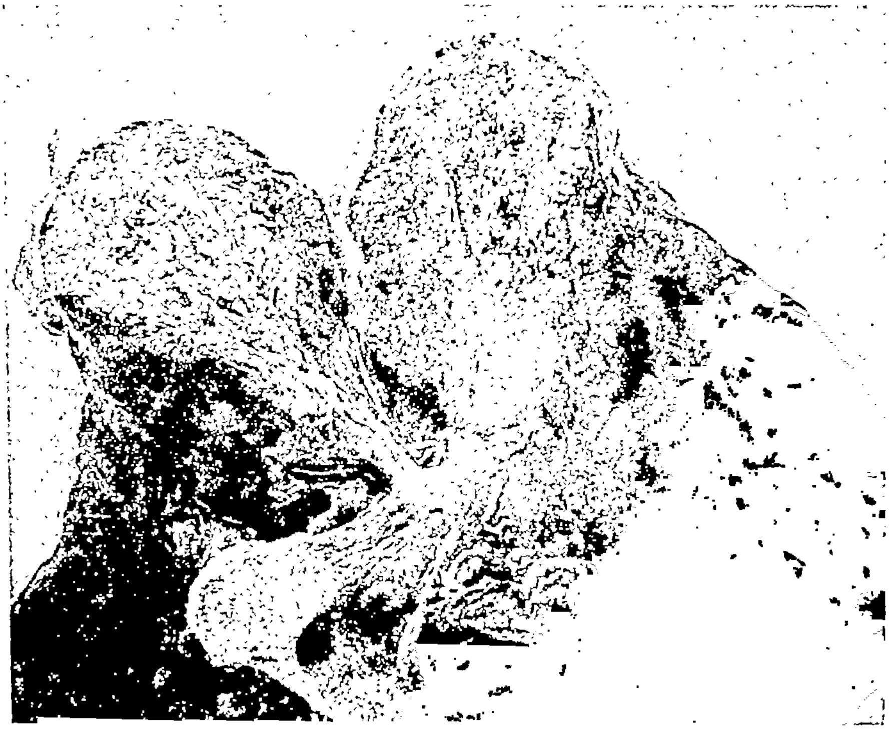

Fig. 9 (Case 171).—Small or oat cell type of bronchiogenic carcinoma of the upper lobe bronchus (see Figs. 3, *b* and 5, *b*). There is marked chronic obstructive pneumonitis, with contracture. The thickening of the visceral pleura overlying the pneumonitic process is evident.

Occasionally, obstructive pneumonitis was present although the neoplasm had not completely obstructed the bronchus. Indeed, in some cases there was a very adequate airway. Nevertheless, there must be, in such cases, physiologic block to the egress of secretions, whether this block is brought about by replacement of ciliated columnar cells by carcinoma cells, which obviously are incapable of ciliary action, or by a splinting of the wall of the bronchus, the result of infiltration by the neoplasm. The occurrence of obstruction in spite of a patent lumen is seen in the common bile duct in carcinoma of the duct.

At what stage in the production of obstructive pneumonitis can the affected lung return to a normal or near normal state, provided the obstructing lesion is removed? At present this question is impossible to answer. Isolated cases in our series would suggest that once the obstruction has been removed, many of these lungs affected by obstructive pneumonitis will clear up. The following case illustrates this point.

REPORT OF CASE

A 30-year-old man came to the clinic complaining of a cough productive of one-half cup of sputum. Associated with the cough were chills and fever. These symptoms had been present for one year. A roentgenogram was reported as showing slight atelectasis of the left lung. Bronchoscopy revealed a neoplasm of the left main bronchus. This lesion histologically proved to be an adenoma of carcinoid type. The endobronchial portion of the tumor was removed. Cough and sputum disappeared entirely, and the roentgenogram one year later was reported as disclosing nothing abnormal. One year and five months later the lung was removed surgically. Grossly, there was no evidence of pneumonitis in the left lung, although there was a residual adenoma in the main bronchus which did not produce obstruction.

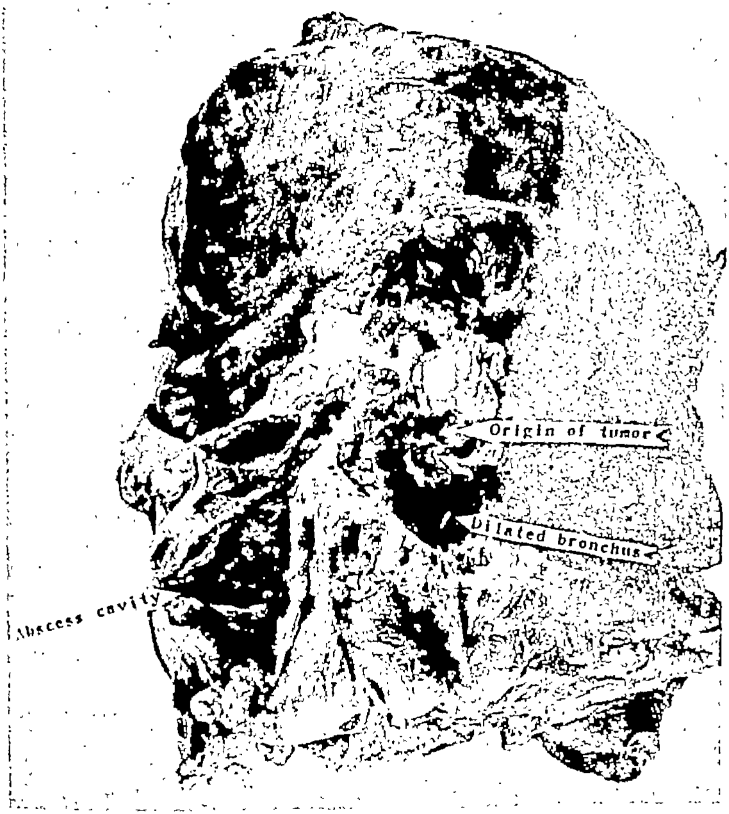

Fig. 10 (Case 27).—Carcinoid type of adenoma of the left main bronchus (see Figs. 1, a and 4, b). Chronic obstructive pneumonitis involves the entire lung. An abscess cavity is situated beneath the pleura, in the lower lobe.

TABLE I. PRESENCE OR ABSENCE OF SPUTUM, GRADE OF PNEUMONITIS, AND SITUATION OF TUMOR IN NEOPLASTIC OBSTRUCTIVE PNEUMONITIS; NEOPLASM: ADENOMA OF BRONCHUS

CASE	SEX	AGE (YR.)	TUMOR LOCATION, BRONCHUS	PNEUMONITIS, GRADE, LOBE	SPUTUM, QUANTITY
1	F	46	L main	0	0
2	F	43	LUL	0	0
3	M	46	RLL	0	0
4	F	45	RUL	0	0
5	M	23	LLL	0	0
6	M	43	LLL	0	0
7	F	61	RML	0	0
8	M	36	LUL	0	0
9	M	17	RUL (peripheral)	0	0
10	M	42	L main	0	0
11	F	36	R main	0	0
12	M	48	RLL*	1 RLL	1
13	M	49	LUL	1 LUL	2
14	F	22	RLL	2 RLL	3
15	F	41	LUL	3 LUL	4
16	M	18	RUL	3 RUL	2
17	M	47	RLL	3 RLL	2
18	F	41	RLL	3 RLL	3
19	F	31	LLL	3 LLL	3
20	M	19	R main	3 RLL	3
21	M	46	RLL	3 RLL, RML	4
22	M	36	L main*	3 L lung	4
23	F	39	L main*	3 LLL, 2 LUL	2
24	M	30	L main	4 LUL	3
25	F	59	LLL	4 LLL	4
26	F	23	L main	4 L lung	4
27	M	29	L main	4 L lung	4
28	F	40	LLL	4 LLL	4
29	F	42	RLL	4 RLL	4
30	M	31	RUL	4 RUL	2
31	M	22	R main	4 RML & RUL	4
32	M	15	R main	4 RUL, 2 RML	4
33	F	39	LUL	4 LUL	3
34	M	46	RLL	4 RLL	4
35	F	25	RLL	4 RLL	3
36	M	30	RLL	4 RLL	4
37	M	30	RLL	4 RLL	1

*Cylindroma type; others are carcinoid type.

AGE AND SEX OF PATIENTS AND DISTRIBUTION OF TYPES OF LESIONS

Twenty-one of the 37 patients who had adenomas (Table I) were males, a percentage of 56. The 2 patients who had alveolar cell carcinoma were females (Table II). Six of the 14 patients who had metastatic malignant processes were males (Table III). One hundred seven of the 118 patients who had bronchiogenic carcinomas (Tables IV, V, VI, and VII) were males, an incidence of 91 per cent. The youngest patient with an adenoma was 15 years old; the

TABLE II. PRESENCE OR ABSENCE OF SPUTUM, GRADE OF PNEUMONITIS, AND SITUATION OF TUMOR IN NEOPLASTIC OBSTRUCTIVE PNEUMONITIS; NEOPLASM: ALVEOLAR CELL CARCINOMA

CASE	SEX	AGE (YR.)	TUMOR LOCATION, BRONCHUS	PNEUMONITIS, GRADE, LOBE	SPUTUM, QUANTITY
38	F	34	LLL (peripheral)	0	0
39	F	57	Entire LLL	0	1

TABLE III. PRESENCE OR ABSENCE OF SPUTUM, GRADE OF PNEUMONITIS, AND SITUATION OF TUMOR IN NEOPLASTIC OBSTRUCTIVE PNEUMONITIS; NEOPLASM: METASTATIC LESIONS

CASE	SEX	AGE (YR.)	TUMOR LOCATION, BRONCHUS		PNEUMONITIS, GRADE, LOBE	SPUTUM, QUANTITY
40	M	36	RLL*		0	0
41	F	33	LUL (peripheral)	D	0	0
42	M	33	RUL (peripheral)	B	0	0
43	F	20	RLL (peripheral)	B	0	0
44	F	51	LUL (peripheral)	A	0	0
45	M	37	RLL (peripheral)	A	0	0
46	F	50	R main	A	0	0-1
47	F	67	L (lung, peripheral)	E	0	1
48	F	54	LLL (peripheral†)	A	0-2	1
49	M	47	LUL (peripheral)	A	1 LUL	1
50	M	38	RUL	C	2 RUL	2
51	F	36	R (lung, peripheral)	E	2	2
52	F	38	R main	A	3 RLL	3
53	M	28	R main	F	3 R lung	3

*Cylindroma primary in trachea.
†Areas of necrosis in tumor.
A, Adenocarcinoma.
B, Fibrosarcoma.
C, Osteogenic sarcoma.
D, Chorionepithelioma.
E, Lymphosarcoma.
F, Grade 4 teratocarcinoma.

oldest was 61 years old; the average mean age was 36.6 years. Among those who had bronchiogenic carcinomas, the youngest patient was 28 years old; the oldest was 69 years old; the average age was 54.1 years. Among the patients who had a metastatic malignant process, the youngest patient was 20 years old; the oldest, 67 years old; the average age was 41.1 years. Of the entire group of neoplasms, 21 per cent were adenomas, 69 per cent were bronchiogenic carcinomas, 8 per cent were metastatic malignancies, and 1 per cent alveolar cell carcinomas. Of the bronchiogenic carcinomas, 47 per cent were the squamous cell type, 27 per cent were the indeterminate large cell type, 9 per cent were the small or oat cell type, and 17 per cent were the adenocarcinoma type.

CORRELATION BETWEEN THE AMOUNT OF OBSTRUCTIVE PNEUMONITIS AND SPUTUM

It is apparent, from an examination of the tables, that there is a very high degree of correlation between the amount and degree of obstructive pneumonitis and the amount of sputum. The fact that sputum is present when a patient has an adenoma as well as when a patient has a bronchiogenic carcinoma is evidence that the replacement of the normal bronchial mucosa with carcinoma, which occurs with remarkable consistency in bronchiogenic carcinoma, is seldom a factor by itself in the production of sputum (Fig. 11, *a* and *b*). Nonneoplastic benign mucosa overlies bronchial adenoma, with the exception of periods in which the patient is bleeding. Except for transient periods, ulceration of the benign mucosa does not overlie the adenoma.

Sputum was present in 26 of the 37 patients who had adenomas and absent in 11, or 29 per cent (Table I). It is misleading to say that a patient never has sputum, because most persons at one time or another can raise secretions from their bronchial trees in the form of sputum, and we are certain that although there were patients who said they did not have sputum, many had minimal amounts at irregular intervals.

TABLE IV. PRESENCE OR ABSENCE OF SPUTUM, GRADE OF PNEUMONITIS, AND SITUATION OF TUMOR IN NEOPLASTIC OBSTRUCTIVE PNEUMONITIS; NEOPLASM: BRONCHIOGENIC CARCINOMA, SQUAMOUS CELL TYPE

CASE	SEX	AGE (YR.)	TUMOR LOCATION, BRONCHUS	PNEUMONITIS, GRADE, LOBE	SPUTUM QUANTITY
54	M	53	L main	0	0
55	M	58	L main	0	0
56	M	44	L main	0	0
57	M	57	RUL	0	0
58	M	58	LUL	0	0
59	M	54	RLL	0	0
60	M	52	RUL	0	0
61	M	53	L main	0	1
62	M	55	RLL*	0	4
63	M	51	RUL	0-3 RUL	1
64	M	57	RLL	0-4 RLL	2
65	M	59	RLL	1	1
66	M	55	LUL	1 LUL	2
67	M	66	LUL	1 LUL	1
68	M	40	L main	1 LLL	1
69	M	60	R main	1 RLL	1
70	M	66	RLL	1 RLL	1
71	M	60	RML	1 RML	1
72	M	59	⅔ L lung	1 LUL	3
73	M	41	LUL	1 LUL	1
74	M	55	RLL*	1 RLL	4
75	M	49	RLL	2 RLL	2
76	M	43	RUL	2 RUL	2
77	M	55	RML	2 RML	1
78	F	58	LUL	2 LUL	1
79	M	44	RLL	2 RLL	3
80	M	54	LLL	2 LLL	2
81	M	62	RLL	2 RLL	3
82	M	54	RLL	3 RLL	4
83	M	46	RLL	3 RLL	2
84	M	60	LLL	3 LLL	2
85	M	61	RUL	3 RUL	4
86	M	48	RLL	3 RLL	2
87	M	51	RLL	3 RLL	2
88	M	60	RLL	3 RLL	4
89	M	52	RLL	3 RLL	3
90	M	55	RUL	3 RUL	4
91	M	55	L main	3 L lung	4
92	M	48	LUL	3 LUL	4
93	M	64	RLL	3 RLL	2
94	M	50	L main	4 LUL	4
95	M	48	RLL	4 RLL	4
96	M	44	RUL	4 RUL	2
97	M	52	LUL	4 LUL	4
98	M	62	LLL	4 LLL	4
99	M	62	RLL	4 RLL	3
100	F	52	R main	4 RLL	4
101	M	69	LUL	4 LUL	3
102	M	49	LLL	4 LLL	4
103	M	48	LLL	4 LLL	3
104	M	51	LLL	4 LLL	2
105	M	39	LUL	4 LUL	3
106	M	57	RLL	4 RLL	4
107	M	50	RUL	4 RUL	4
108	M	56	RLL	4 RLL	3

*Central necrosis of tumor.

TABLE V. PRESENCE OR ABSENCE OF SPUTUM, GRADE OF PNEUMONITIS, AND SITUATION OF TUMOR IN NEOPLASTIC OBSTRUCTIVE PNEUMONITIS; NEOPLASM: BRONCHIOGENIC CARCINOMA, INDETERMINATE LARGE CELL TYPE

CASE	SEX	AGE (YR.)	TUMOR LOCATION, BRONCHUS	PNEUMONITIS, GRADE, LOBE	SPUTUM, QUANTITY
109	F	58	LUL	0	0
110	M	55	LUL	0	0
111	M	38	R (superior sulcus)	0	0
112	M	54	RUL (peripheral)	0	0
113	M	57	LUL	0	0
114	M	57	LUL	0	0
115	F	50	RUL (peripheral)	0	0
116	M	55	RLL (peripheral)	0	0
117	M	51	Entire RML	0	0
118	M	37	Entire RUL	0	0
119	M	43	LUL (peripheral)	0	0
120	M	64	RLL (peripheral)	0	0
121	M	59	LLL	0	0
122	F	28	L main	0	0
123	M	60	RLL (peripheral)	0	0
124	F	50	LLL (peripheral)	0	0
125	M	58	RLL (peripheral)	0	0
126	M	56	RUL	0	0-1
127	M	50	LUL (peripheral)	0	0-1
128	M	56	RUL (peripheral)*	0	1
129	M	46	LUL*	0	1
130	F	60	RLL (peripheral)*	0	1
131	M	66	RUL (peripheral)*	0-2 RUL	1
132	M	64	L main	1 LLL	1
133	M	64	L main	1-3 L lung	1-2
134	M	33	RUL	1 RUL	1
135	M	62	RLL	2 RLL	2
136	M	59	R main	2 RUL, 3 RLL	4
137	M	56	RUL	2 RUL	1
138	M	52	LLL	3 LLL	3
139	M	51	LLL	3 LLL	3
140	M	48	LUL	3 LUL	2

*Central necrosis of tumor.

TABLE VI. PRESENCE OR ABSENCE OF SPUTUM, GRADE OF PNEUMONITIS, AND SITUATION OF TUMOR IN NEOPLASTIC OBSTRUCTIVE PNEUMONITIS; NEOPLASM: BRONCHIOGENIC CARCINOMA, ADENOCARCINOMA TYPE

CASE	SEX	AGE (YR.)	TUMOR LOCATION, BRONCHUS	PNEUMONITIS, GRADE, LOBE	SPUTUM, QUANTITY
141	F	58	RUL (peripheral)	0	0
142	M	60	RUL (peripheral)	0	0
143	M	40	LUL (peripheral)	0	0
144	M	64	RUL	0	0
145	M	57	L main	0	0
146	M	54	LLL (peripheral)	0	0
147	F	58	RUL (peripheral)	0	0
148	M	63	RLL (peripheral)	0	0
149	M	51	RLL	0	0
150	F	50	LUL (peripheral)	0	0
151	M	55	LLL (peripheral)*	0	1
152	M	58	RLL (superiorly)†	0	2
153	M	60	LLL	0-3 LLL	2
154	M	49	LUL (peripheral)	1 LUL	1-4
155	M	38	R main	2 RLL	3
156	M	57	RLL	2 RLL	2
157	M	59	RLL	2 RLL	1
158	M	60	LUL	3 LUL	3
159	M	47	R main	3 R lung	4
160	M	37	R main	4 R lung	4

*Central necrosis of tumor. †Pulmonary infarction.

Table VII. Presence or Absence of Sputum, Grade of Pneumonitis, and Situation of Tumor in Neoplastic Obstructive Pneumonitis; Neoplasm: Bronchiogenic Carcinoma, Small or Oat Cell Type

CASE	SEX	AGE (YR.)	TUMOR LOCATION, BRONCHUS	PNEUMONITIS, GRADE, LOBE	SPUTUM, QUANTITY
161	M	49	RUL (peripheral)	0	0
162	M	56	LUL	0	0
163	M	66	RLL	0	0
164	M	54	LUL	1 LUL	1
165	F	45	LLL	1 LLL	1
166	M	56	R main	1 RLL	1
167	M	48	R main	1 RLL	1
168	M	56	RML	2 RML	2
169	M	52	L main	3 LLL	2
170	M	56	RLL	3 RLL	2
171	M	53	LUL	4 LUL	4

Of 2 patients who had alveolar cell carcinoma (Table II), one gave no history of sputum and the other gave a history of minimal amounts of it.

Thirty-seven, or 31 per cent, of 118 patients who had bronchiogenic carcinoma gave no history of sputum (Tables IV, V, VI, and VII). Among the several types of bronchiogenic carcinoma, it is evident that the more peripheral the situation of the carcinoma tended to be, the less was the chance for the development of sputum. This was particularly true of the adenocarcinoma type of lesion and of the large cell indeterminate type. The reason for this, it would

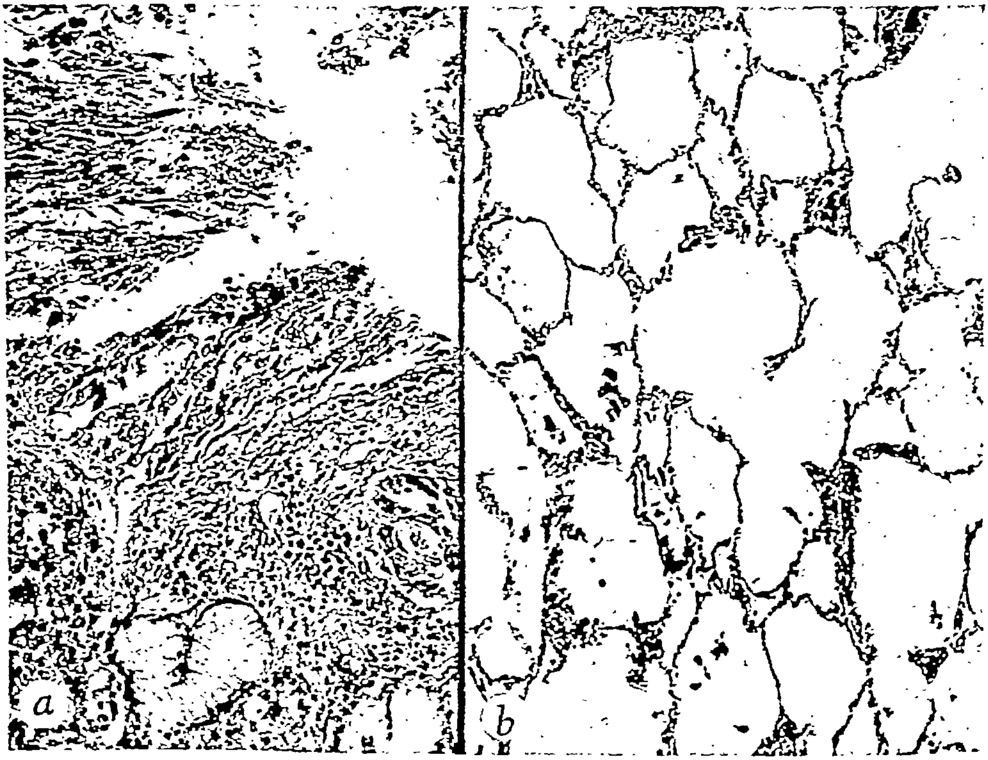

Fig. 11 (Case 61).—*a*, Squamous cell bronchiogenic carcinoma of the left main bronchus: the normal bronchial mucosa is replaced by carcinoma (×150); *b*, the peripheral pulmonary tissue in the same case is normal (×100). (Hematoxylin and eosin stain.)

seem, is that these lesions tend to be more peripherally situated than do the other types of bronchiogenic carcinoma, and this peripheral location means that the chance of their obstructing a larger bronchus and producing obstructive pneumonitis is diminished.

In the group of 14 patients who had metastatic neoplasms, 6 had no sputum (Table III).

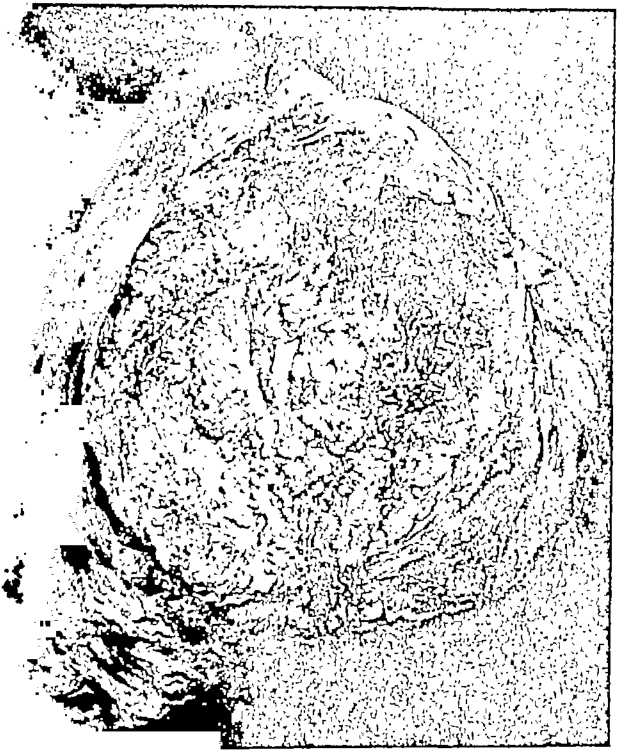

Fig. 12 (Case 62).—A large, squamous cell type of bronchiogenic carcinoma of the right lower lobe (see Fig. 3, *a*), with massive necrosis and cavitation of the central portion of the tumor. The necrotic central portion of this tumor was the factor which produced copious sputum in the patient (Table IV).

In a small percentage of cases, there was not an absolute correlation between the quantity of sputum and the severity of obstructive pneumonitis. It was felt that when lack of correlation did occur, it frequently could be explained on the basis of central necrosis of the tumor (Figs. 12 and 3, *a*). In such instances, the neoplasm was large and the central portion of the tumor had undergone necrosis and had evacuated through a bronchus, producing sputum.

This evacuation of the necrotic center of the tumor produces an excavating carcinoma. The onset of sputum, under these circumstances, usually is sudden, and the sputum itself is voluminous. It is noteworthy that such evacuation did not occur in association with any of the adenomas which, because of their slow growth, as a rule do not exhibit necrosis. In one instance (Case 117) there was infarction of nonneoplastic peripheral pulmonary tissue, which it was felt accounted for the production of sputum.

We are unable to find any correlation between (1) the presence or absence of sputum and the amount of sputum with (2) the duration of symptoms. We considered the possibility that the presence or absence of sputum and the amount of sputum might depend, to some extent, on whether the lesions were situated in the upper or lower lobe, inasmuch as there is more dependent drainage from the upper lobe. This did not prove to be the case.

Certain patients who had bronchiogenic carcinoma do not have any sputum, and in such cases if the carcinoma is inaccessible bronchoscopically, the only way to obtain cellular proof of the carcinoma is to examine secretions removed bronchoscopically. However, as has been stated, it is our feeling that many patients who have cancer of the lung can produce a small amount of sputum which may be adequate for cytologic examination. It would appear that the presence of measurable amounts of sputum, since it is dependent upon pneumonitis, *is not an early symptom of primary carcinoma of the lung.*

SUMMARY

We have described the histopathologic changes in the periphery of the lung secondary to an obstructing neoplasm of the bronchus.

It was felt that it would be more nearly accurate to term this condition "obstructive pneumonitis" rather than the commonly employed term, "atelectasis."

We have shown that there is a very high degree of correlation between the presence of this type of pneumonitis and the presence of sputum.

REFERENCES

1. Dudgeon, L. S., and Wrigley, C. H.: On the Demonstration of Particles of Malignant Growth in the Sputum by Means of the Wet-film Method, J. Laryng. & Otol. 50: 752-763, 1935.
2. Samper, Rafael: Vascular Changes Secondary to Carcinoma of the Lung, Thesis, Graduate School, University of Minnesota, 1946, 34 pp.

(See discussion on page 122.)

CYTOLOGY OF BRONCHIAL SECRETIONS

Its Role in the Diagnosis of Cancer

William L. Watson, M.D., and (by invitation) Henry Cromwell, M.D.,
Lloyd Craver, M.D., and George N. Papanicolaou, M.D.
New York, N. Y.

THIS discussion attempts to present the experience of the clinician and the surgeon with the method of cellular study of bronchial secretions in relation to the diagnosis of cancer, and to evaluate statistically our findings with those previous reports on this topic which have come for the most part from the cytologist, the pathologist, or the endoscopist.

Papanicolaou, who has done so much to establish on a sound footing the cell smear method of diagnosing cancer, has himself pointed out that there is nothing new in this method, and the historical fact is that the examination of body fluids for the detection of cancer cells dates back to the nineteenth century. Beale (1860), Sanders (1864), Quincke (1875), and Hampeln (1876) succeeded in identifying cancer cells in sputum. Dudgeon and Wrigley of England (1935), and Wandall of Denmark (1944) have reported good results in their examination of sputum smears for neoplastic cells.

On June 22, 1945, the first sputum specimen in the series under discussion was smeared and studied at New York Hospital. The material was from an obscure case of Cromwell's, in which there was a clinical suspicion of cancer of the lung. The patient had a serosanguineous sputum and the x-ray findings were suggestive. The sputum smears were not particularly good and disclosed nothing unusual except for one group of cells with enlarged heterogeneous and hyperchromatic nuclei. These were diagnosed as a group of malignant cells and the subsequent bronchoscopy revealed no definite endobronchial changes, but at thoracotomy, a nonresectable lung cancer was revealed. A mediastinal node excised at this time proved the growth to be an undifferentiated type of bronchiogenic carcinoma.

CLINICAL MATERIAL

Following this initial success, it soon became evident that a detailed cytologic study of sputa and bronchial secretion obtained from a large number of persons afflicted with a variety of pulmonary and bronchial diseases would be necessary before the differential, diagnostic value of the smear procedure in the detection of pulmonary cancer could be determined.

Bronchial secretions or sputa have been studied in a series of 1,200 cases, and the number of specimens studied for each patient varied from one to seven. A majority of the earlier patients, however, suffered from inflammatory lung conditions rather than cancer, and so for the clinical portion of

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From the Thoracic Surgical Service, Memorial Hospital.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

In each of 18 cases in which operation has been undertaken on the basis of a Class V cytology report, the diagnosis has been confirmed. At Memorial Hospital 7 pneumonectomies have been correctly undertaken when the only positive preoperative histologic evidence to justify the procedure was a Class V report on sputum or bronchial washing.

In the present series of 236 bronchiogenic cancers, there have been 141 positive reports (Classes IV and V), giving an accuracy rate of 60 per cent.

Table II

Cases studied	400	
Proved bronchiogenic cancer	236	
Positive sputa	112	60%
Positive bronchial aspirate	27	

The percentage of accurate positive reports in the recent cases is nearly 90 per cent.

CASE REPORTS

Case 1.—W. M., a man, 56 years of age, complained of chest pain of eight months' duration, a chronic cough, profuse sputum, and fourteen pounds loss of weight. Physical examination revealed suppressed breath and voice sounds of the right lower chest.

X-ray Report.—X-ray examination showed segmental atelectasis of the paravertebral segment of the right lower lobe with no definite clue from the films as to the etiology. An endobronchial tumor as well as bronchiectasis had to be considered as possibilities. Bronchoscopic examination was advised in view of the possibility of bronchiogenic cancer.

Bronchoscopy.—Bronchoscopy findings were entirely negative.

Bronchial Washings.—There was conclusive evidence of a malignant neoplasm, most likely a bronchiogenic cancer, Class V.

Gross Specimen.—The right lung was removed by pneumonectomy. On the lateral posterior portions of the lower lobe the pleura was puckered and a nodule was palpable beneath it. At the bifurcation of the right lower lobe bronchus a creamy white, firm, infiltrating tumor was noted. Distal to this the lung tissue was firm and on section the bronchi and bronchioles were dilated and contained yellowish-green, thick, puslike material. Sections through the posterolateral portion of the lower lobe showed multiple areas of firm, yellowish-gray tissue lying immediately below the pleura and surrounded by noncrepitant dirty, gray-brown lung tissue. At the point where the cancer began in the bronchus there was a 1½ cm. node, and in the hilus there were four soft nodes.

Microscopic Study.—Bronchiogenic epidermoid carcinoma, grade II, was found. The extrapulmonary nodes showed no tumor. Bronchopulmonary nodes were positive for cancer.

Case 2.—D. W., a man 50 years of age, complained of a slight cough. He gave a history of having had virus pneumonia in August, 1947, and again in December, 1947. January, 1948, Monilia were found on pure culture. Physical examination revealed moist râles in the right posterolateral base of the lung and an old right apical tuberculosis.

X-ray Report.—In the right lower lung field, there was a two-inch patch of infiltration with ill-defined borders. There were a few productive, tuberculous changes in the right infraclavicular region. Findings seemed most consistent with an inflammatory process.

Bronchoscopy.—Findings at bronchoscopy were entirely negative.

Bronchial Washings.—There was conclusive evidence of a malignant neoplasm. Malignant cells were numerous, Class V.

Gross Specimen.—The specimen consisted of the entire right lung. In the apex were two firm, partly calcified nodules. The upper and middle lobes were otherwise normal and the upper portion of the lower lobe was not remarkable. The basal portion of the lower lobe was almost completely replaced by a large moderately firm tumor mass measuring 11 by 10 by 8 cm. It was smooth, firm, pinkish-yellow in color and extended to the visceral pleura

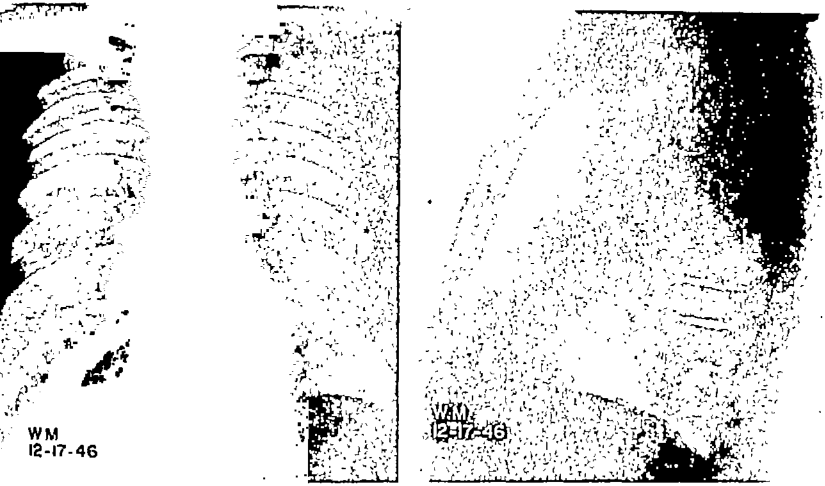

Fig. 1 (Case 1).—Chest radiographs showing segmental atelectasis of the paravertebral segment of the right lower lobe.

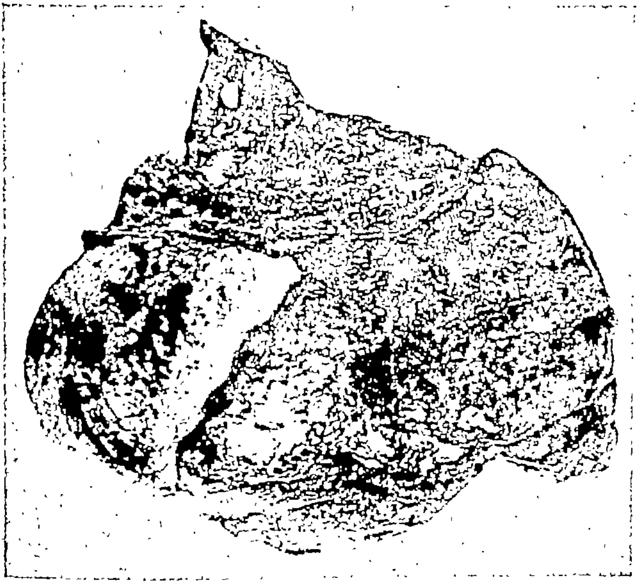

Fig. 2 (Case 1).—Gross specimen consisting of the entire right lung. It reveals an en cancer of the lateral, posterior portion of the lower lobe with surrounding pneumonitis abscess formation. The middle and upper lobes are inflated.

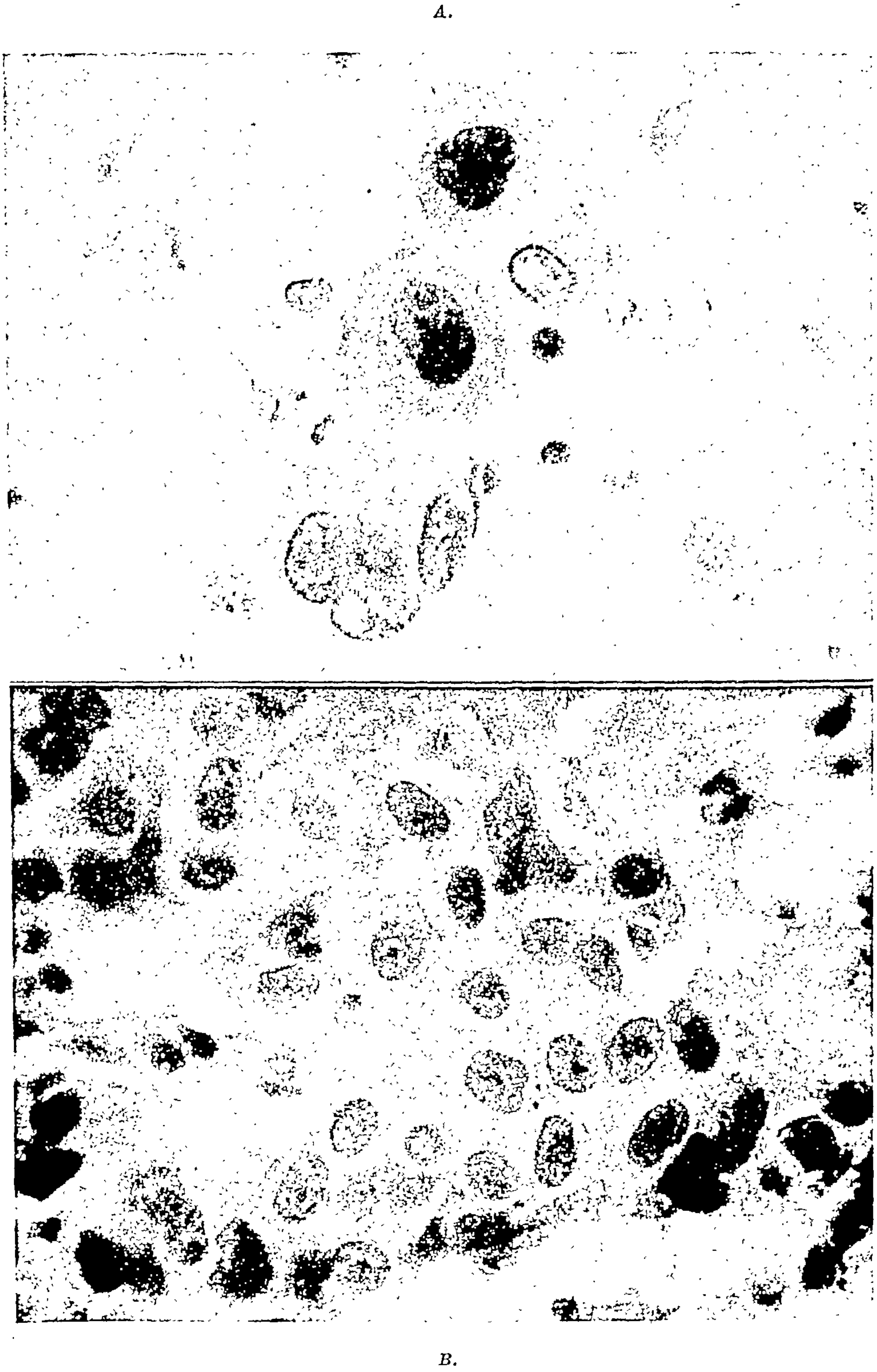

Fig. 3 (Case 1).—*A*, Bronchial washing specimen showing cancer cells, Class V. *B*, Formal histologic section of the operative specimen showing epidermoid carcinoma, Grade II.

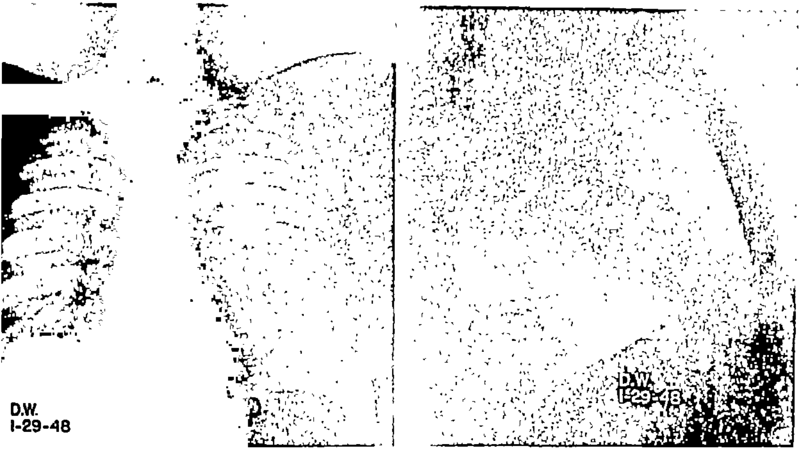

Fig. 4 (Case 2).—Chest radiographs showing a 6 cm. patch of infiltration with ill-defined borders in the right lower lung field thought to be consistent with an inflammatory process.

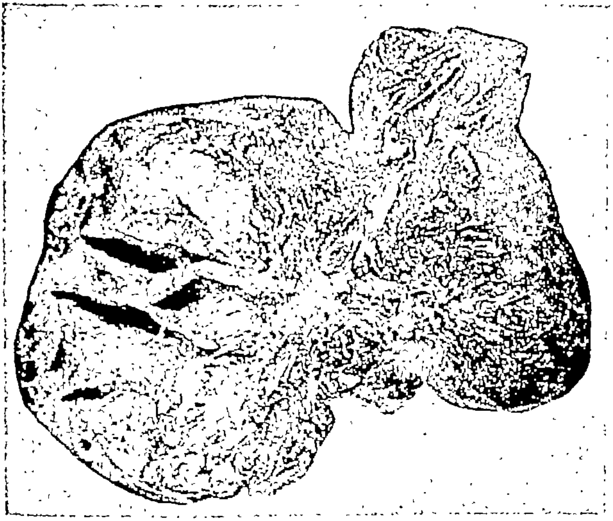

Fig. 5 (Case 2).—Gross specimen consisting of an entire right lung. The basal portion of the lower lobe is almost completely replaced by tumor but without ulceration of bronchus or bronchioles.

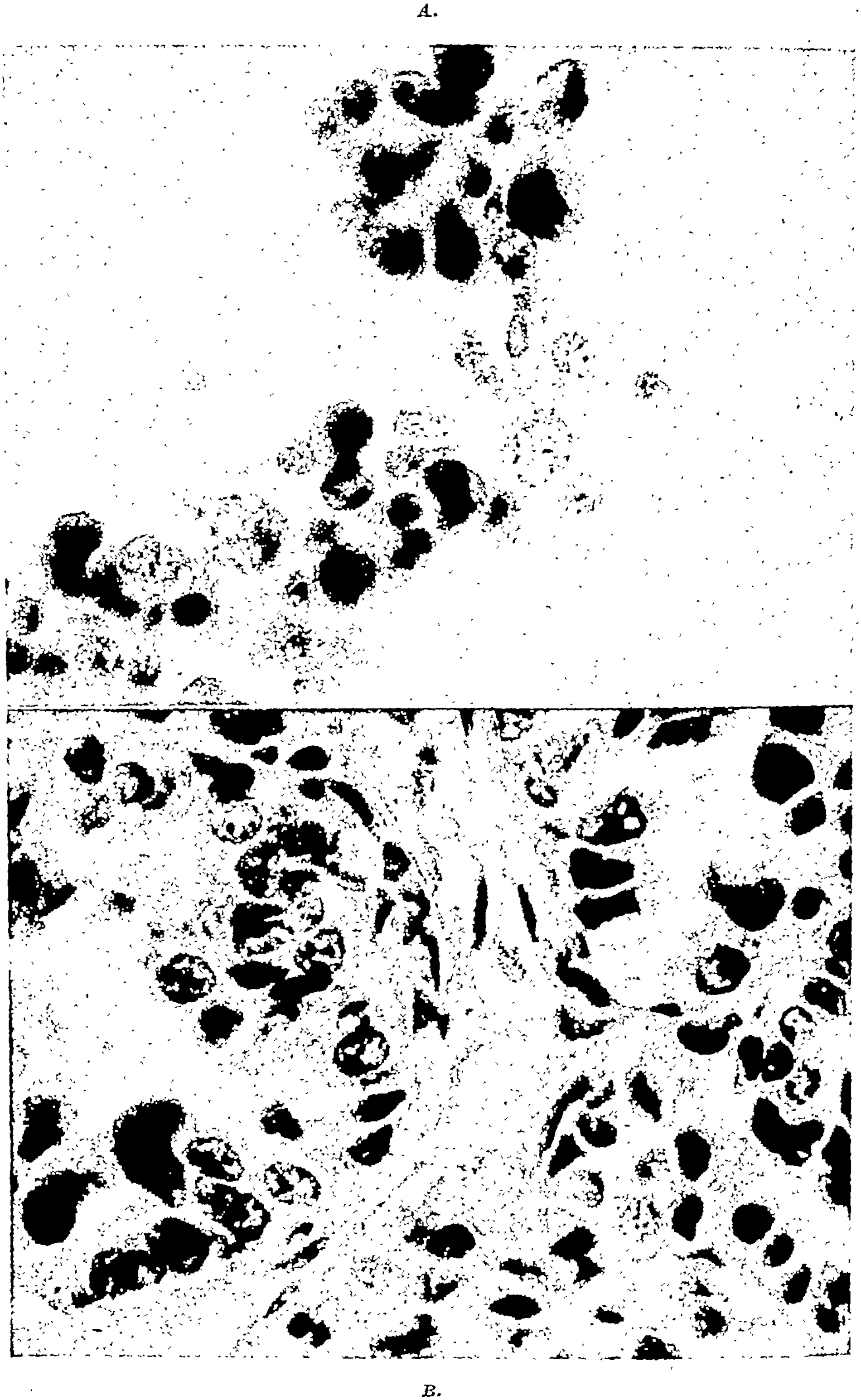

Fig. 6 (Case 2).—*A*, Bronchial washing specimen showing conclusive evidence of bronchiogenic cancer, Class V. *B*, Formal histologic section of the operative specimen showing peripheral bronchiolar carcinoma of lung, grade II. It has some papillary and pseudoglandular features.

over a wide area. Distinct subpleural nodules similar to the main tumor were seen nearby, but there was no ulceration of the bronchus or bronchioles.

Microscopic Study.—Carcinoma of the lung, grade II, peripheral bronchiolar type having papillary and pseudoglandular features was reported. About the main tumor were multiple satellite tumor bodies. It could not be ascertained whether these represented multicentric primary growths or whether their source was from the main bulk of the tumor. Two hilar nodes showed metastatic cancer.

COMMENTS AND CONCLUSIONS

The method of examination of sputa and bronchial secretions for cancer cells has become a routine with us in every case in which an intrathoracic neoplasm is suspected. It has become an additional, complementary, diagnostic measure. It is not a substitute for the already well-established and reliable methods previously used in establishing the diagnosis of lung cancer.

It is apparent, however, that cytologic studies will sometimes be the only way in which lung cancer can be definitely diagnosed prior to operation. Competent cytologists believe their positive smear diagnosis of pulmonary cancer is as trustworthy as that made by the pathologist from a study of a histologic section of tissue removed at biopsy. Many conscientious thoracic surgeons feel more confident about proceeding with radical surgery when a positive diagnosis has been established microscopically.

In our busy outpatient department, we find that cytologic studies tend to lessen the interval between the first clinic visit and admission to the hospital for surgical care. Because we have a limited inpatient bed capacity, the procedure has helped us to select suitable cases for admission and to cut down the number of days of hospitalization prior to surgery.

Four hundred consecutive admissions to Memorial Hospital were studied. There were 236 cases of proved bronchiogenic cancer. There were 112 positive sputum reports and 29 positive bronchial washings, a positive cytologic diagnosis in 60 per cent of the cases.

There were 176 bronchoscopies, and 63 positive biopsies were obtained (37 per cent); 98 aspiration biopsies were done and 85 positive reports returned (86 per cent).

TABLE III

Proved bronchiogenic cancer	236
Bronchoscopies	176
Positive bronchoscopic biopsy	63—36%
Aspiration biopsy of lung	98
Positive aspiration biopsy	85—86%

A positive bronchoscopic diagnosis of cancer was obtained in 36 per cent of the cases and 86 per cent of the aspiration biopsies of lung were positive.

Practically all of the patients in this series had had a recent diagnosis of pneumonia *made by their family doctors.* If the thoracic surgeon is to cure more patients with bronchiogenic cancer, he must have more early cases, and one way to get these early cases is for the internist to view with suspicion each case of "atypical pneumonia" in a patient over 35 years of age, and every patient with recurring "virus pneumonia" or "unresolved pneumonia" should have a bronchoscopy and complete cytologic studies. A diagnosis of pneumonia probably is not justified if subsequent radiographs of the chest do not show the absence of pneumonia. Early cases will be found also on routine chest x-ray studies and mass survey.

Early, operable, and curable cases of bronchogenic carcinoma can be detected by cytologic measures.

REFERENCES

1. Herbut, Peter A., and Clerf, Louis H.: Bronchogenic Carcinoma; Diagnosis by Cytologic Study of Bronchoscopically Removed Secretions, J. A. M. A. 130: 1006-1012, 1946.
2. Papanicolaou, George N.: Diagnostic Value of Exfoliated Cells From Cancerous Tissues, J. A. M. A. 131: 372-378, 1946.
3. Papanicolaou, George N.: The Cell Smear Method of Diagnosing Cancer, Am. J. Pub. Health 38: 1948.

DISCUSSION ON "OBSTRUCTIVE PNEUMONITIS OF NEOPLASTIC ORIGIN" BY DR. JOHN MC DONALD, DR. STUART W. HARRINGTON, AND DR. O. THERON CLAGETT;* AND "CYTOLOGY OF BRONCHIAL SECRETIONS" BY DR. WILLIAM L. WATSON, DR. HENRY CROMWELL, DR. LLOYD CRAVER, AND DR. GEORGE N. PAPANICOLAOU

DR. JOHN H. GIBBON, JR., Philadelphia.—We have complete confidence in a diagnosis of cancer of the lung based upon the finding of neoplastic cells in the bronchial secretions. We reported upon this method last year before this Association. I was particularly pleased to hear Dr. Watson speak of false positive diagnoses. The method actually will be of little use if there is a false positive. Two years ago, we made one false positive diagnosis. This patient had a large pulmonary abscess and we did a pneumonectomy. We have had no false diagnoses since then.

I think it is only fair to the pathologists to say that they frequently need more than one specimen to make a positive diagnosis. Bronchoscopy has been done in some of our patients four or even five times before the pathologist has been able to find neoplastic cells in the bronchial secretions. Sometimes if there is adequate clinical evidence we operate without a positive tissue or cellular diagnosis.

The incidence of positive finding of neoplastic cells in the bronchial secretions is approximately 90 per cent, which is quite high. The incidence of positive tissue diagnosis is between 40 and 50 per cent. I think these two authors are to be congratulated on this very interesting addition to our diagnostic procedures in this disease.

DR. JOHN W. STRIEDER, Boston.—I should like briefly to record our experience at The Boston City Hospital. Dr. Donald McKay and Dr. Paul Ware have been working on this diagnostic method for three years and have examined more than 1000 smears. That does not mean 1,000 cases, but, as has been suggested, we believe that at least three readable smears should be examined before they are considered to be of diagnostic value for a given case. It is of interest to discuss the two methods (sputum and bronchial secretions), as to whether one or the other is of greater value in the study of exfoliated tumor cells. Perhaps both specimens should be used in the given case so that maximum diagnostic precision may result. Tumor cells in the sputum may come from the larynx or esophagus, but it should be simple to rule these tumors out. It is the late suppurative pulmonary lesion, that is frequently accompanied by roentgenographic change, in which diagnosis by sputum examination is easiest. I would like to mention the simplified method of obtaining bronchial secretions for smear by means of the aspirating tube that Dr. Ware has devised† and that is now being made by Pilling. By means of this tube, secretions may be taken with considerable precision from a suspected zone in the bronchial tree.

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*See page 97 for article by McDonald, Harrington, and Clagett.

†Now being manufactured by George P. Pilling & Son Co., Philadelphia, Pa.

Table I is a summary of 170 cases among which were 54 cases of bronchiogenic carcinoma.

TABLE I

Total number of bronchoscopic cases	170
Number of cases of bronchiogenic carcinoma	54
(a) Histologic diagnosis	48
(b) Clinical diagnosis	6
Positive smears (54 cases of carcinoma)	40 (74%)
False negative smears (Carcinoma present; smear negative)	14 (26%)
False positive smears (No carcinoma; smear positive)	3
Total number of errors	17 10%)

	Total smears	Positive	Negative
Bronchoscopy positive	29 (54%)	26 (48%)	3 (6%)
Bronchoscopy negative	25 (46%)	14 (26%)	11 (20%)
Total	54 cases	40 (74%)	14 (26%)

It will be seen that 6 cases of histologically unproved carcinoma are included in the 54. These seemed, clinically, to be unequivocal cases of bronchiogenic cancer and were included because they test the method under adverse statistical circumstances. If they are excluded, the percentage of positive smears (in 48 proved cases) rises to 83 per cent, and the positive bronchoscopic tissue diagnoses to 60 per cent.

DR. CLARENCE CRAFOORD, Stockholm.—The pathologists with whom we are working are always very cautious when stating whether or not cells in smears from the sputum are positive for malignancy. Because of that we have tried as far as possible to get bronchoscopic biopsy specimens for them. By using specially constructed bronchoscopic biopsy forceps the incidence of positive biopsies can be considerably increased. We now use flexible thin forceps with which we can go out into small bronchial branches with the guidance of x-ray in order to get small pieces of tissue from diseased areas. In many of these cases the biopsy is taken far beyond the field of vision in the bronchoscope. By this means we now have positive biopsy answers in about 80 per cent of our cases of carcinoma of the lung.

DR. McDONALD.—I had not intended to discuss the results that we have had in studying sputum and bronchial secretions for cancer cells, but I believe that a few words might be said. At the present time, we have had somewhat more than 200 cases in which we have made a positive diagnosis on the basis of sputum or bronchial secretions or both, and we feel gratified with the accuracy and results of this method of examination. We believe that it is a valuable diagnostic aid.

DR. WATSON.—I would like to say that each patient coming through our Thoracic Clinic has cytologic studies carried out on several sputum specimens while he is an outpatient, and when hospitalized and bronchoscoped the suspected bronchus is always washed with saline and the aspirated material studied for tumor cells. Bronchial washings may be positive before the patient has begun to produce enough sputum for study.

Cytology institutes and some private medical laboratories are now set up to study and report on sputum specimens sent in by the family doctor. This increase in the range of usefulness of the cytology method should lead to the discovery of unsuspected early bronchiogenic carcinomas suitable for surgery.

Each suitable patient suspected of having bronchiogenic carcinoma should have a bronchoscopy, and, if the diagnosis cannot be established by biopsy, a bronchial aspirate of the suspected bronchus should be obtained.

INTRATHORACIC MENINGOCELE

HARVEY J. MENDELSOHN, M.D., AND EARLE B. KAY, M.D.
CLEVELAND, OHIO

IT IS now accepted that surgical exploration and, if possible, extirpation is the treatment indicated for benign, malignant, and potentially malignant tumors and cysts of the mediastinum. Although the differential diagnosis of these lesions has increased in accuracy, occasionally involvement of the mediastinal lymph nodes by tuberculosis, Hodgkin's disease, or one of the lymphomas cannot be distinguished preoperatively. Usually this is of no consequence. A biopsy is taken at the time of exploration, the diagnosis is established, and treatment can then be started on a rational basis. However, any means by which differential diagnosis can be improved and unnecessary exploration can be avoided should be sought. For this reason and because of the rarity of the lesion, a case of mediastinal meningocele simulating mediastinal neurofibroma is reported.

CASE REPORT

C. T., a 40-year-old white woman, was admitted to the Thoracic Surgical Service of Cleveland City Hospital on Aug. 8, 1946, for treatment of an intrathoracic tumor first diagnosed in March, 1946, following a routine photo-fluoro-roentgen survey by the Cuyahoga County Tuberculosis Clinic. The patient had no symptoms at this time. In May, 1946, she developed mild attacks of dyspnea and substernal oppression lasting only a few hours. These attacks increased slightly in duration and severity during the next few months.

The significant findings on physical examination at the time of admission were numerous cutaneous and subcutaneous nodules and a few café au lait spots, all typical of generalized neurofibromatosis. The only other significant findings were confined to the radiologic examination of the chest and thoracic spine. X-rays of these areas as demonstrated in Fig. 1 (*A*, *B*, and *C*) showed a homogeneous ovoid mass in the right paravertebral gutter adjacent to the sixth, seventh, eighth, and ninth thoracic vertebrae and four 1.5 cm. circular defects involving the posterior portions of the bodies of these vertebrae and the regions of their spinal nerve foramina.

The tentative diagnosis was posterior mediastinal neurofibroma, probably multiple, involving the adjacent vertebrae with hourglass extension into the spinal nerve foramina. Neurological examination showed no evidence of intradural involvement. Reflexes, sensation, and muscle powers were normal throughout. Spinal fluid was normal as were the spinal fluid dynamics. In view of these findings, it was felt that an exploratory thoracotomy was indicated.

Operation.—On Aug. 12, 1946, under intratracheal anesthesia, a right posterolateral incision was made through the bed of the resected eighth rib and the tumor was exposed transpleurally. A cystic tumor, measuring 3 by 4 by 8 cm. and covered by parietal pleura, was found just lateral to the bodies of the sixth, seventh, and eighth thoracic vertebrae. It was apparent that the mass was not a neurofibroma, but that it communicated with the subarachnoid space of the spinal canal through one of the circular defects seen in the x-ray views. In attempting to free the cyst from the parietal pleura, the cyst was entered and several ounces of thin, clear, colorless, watery fluid escaped. The cyst was then widely opened and found to communicate through the enlarged seventh spinal nerve foramen with the spinal subarachnoid space. (Fig. 2.) A normal spinal cord and nerve roots could be seen in their usual positions. The defects in the other three adjacent spinal nerve foramina could be seen and felt. They were covered with parietal pleura which bulged moderately before the cyst was opened. These areas were not disturbed.

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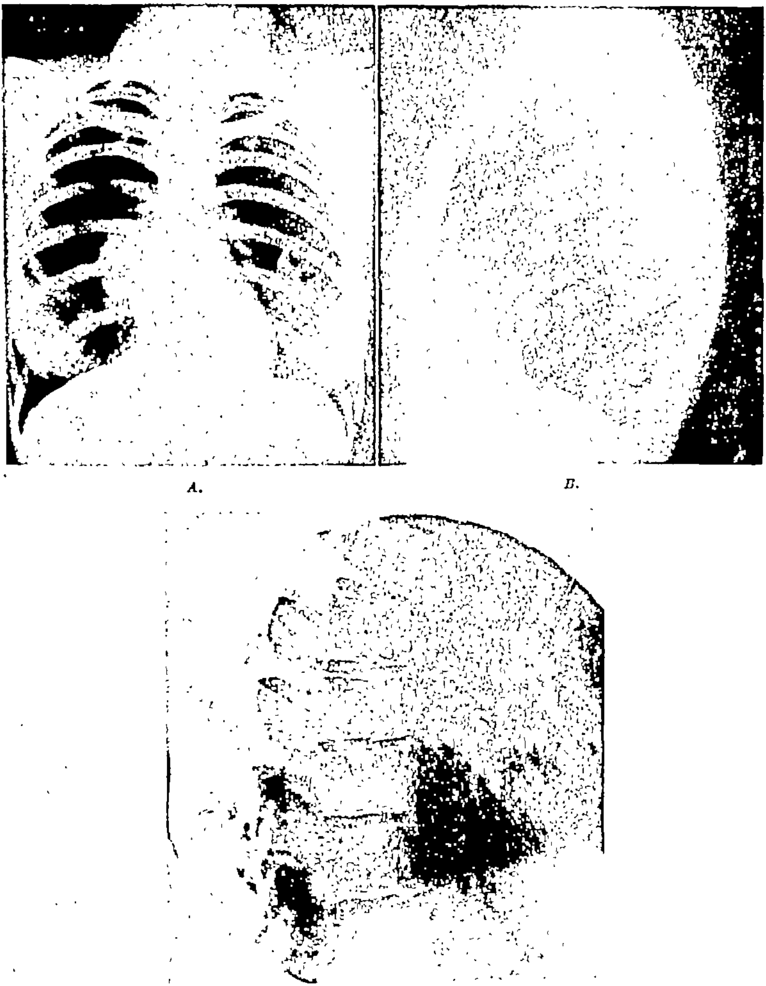
The cyst wall was smooth, glistening, and very thin. No solid tumor or association of the cyst with a nerve was found. The neck of the cyst was freed from the parietal pleura and the defect into the subarachnoid space was closed by imbricating the cyst wall and the parietal pleura with interrupted silk sutures. A small amount of talc was sprinkled over the pleura in this area to promote fibrosis. The lung was re-expanded and the incision was then closed in layers, without drainage.



A. *B.*

C.

Fig. 1.—*A*. Posteroanterior film of chest showing lesion on right; *B*, right lateral view of chest showing lesion in midposterior region over defects of vertebral bodies; *C*, cone down lateral view showing defects in posterior aspects of bodies of the sixth, seventh, eighth, and ninth thoracic vertebrae.

The postoperative course was uneventful except for moderate headache and backache, which disappeared in a few weeks. There was no reappearance of dyspnea. X-ray examination immediately following operation showed the tumor to be almost completely gone, but roentgenograms nine days and one month after the operation showed a complete recurrence. X-ray pictures one year later (Fig. 3) showed a complete regression and the patient continues to be well except for low back pain with sciatic radiation suggestive of a herniated intervertebral disc. However, the patient refuses further investigation.

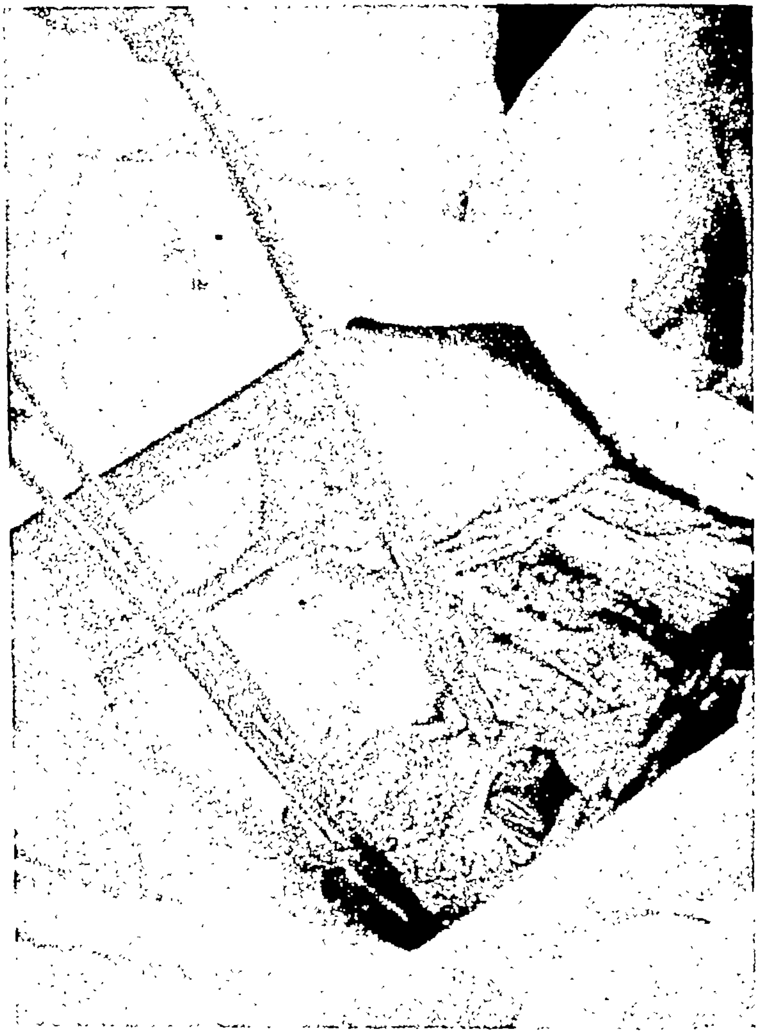


Fig. 2.—Cyst opened at operation showing defect into spinal canal at end of aspirator tip.

The incidence of intrathoracic meningocele must be rare for Thompson[1] did not mention it in his complete review of the literature on mediastinal tumors and cysts, which includes large series by Blades,[2] Heuer and Andrus,[3] and others. Heuer's[4] study of hourglass tumors of the spine did not include any cystic lesions that could be called meningoceles. Schmorl and Junghanns[5] mentioned only solid hourglass tumors as causing enlargement of the spinal nerve foramina.

Pohl[6] in 1933 reported the first case of mediastinal meningocele noted in the literature. This was in a 47-year-old woman with a right convex kyphoscoliosis of the upper thoracic spine. She also had a generalized cutaneous neurofibromatosis. The patient consulted a doctor because of the "grippe."

Dullness was found in the right upper part of the chest, an x-ray examination was ordered, and a large, oval, well-demarcated, homogeneous shadow was seen in the right upper posterior part of the chest adjacent to the spine. With a tentative diagnosis of neurofibroma, the chest was explored transpleurally. A 2 cm. defect was found in the lateral wall of the fourth thoracic vertebra through which the neck of the spinal fluid-containing cyst communicated with the spinal canal and the subarachnoid space. The cyst was emptied and the defect closed with a muscle flap. The patient died from an empyema.

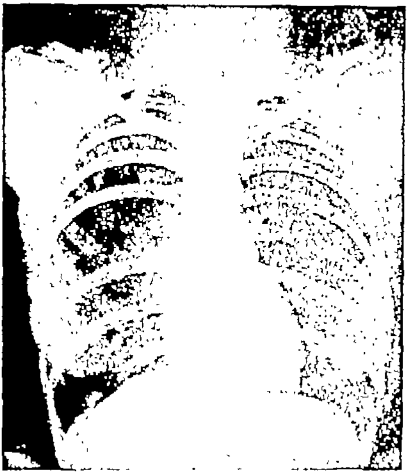


Fig. 3.—Posteroanterior film of chest one year after operation; no tumor visible.

Cabello-Campos[7] in 1946 reported two cases apparently diagnosed without operation, both in the right side of the chest. One of these patients had cutaneous neurofibromatosis and both had other congenital defects (spina bifida and congenital lung cyst). He made the statement that if one thinks of this lesion, it can be diagnosed clinically. Freedlander[8] operated on a middle-aged woman with cutaneous neurofibromatosis who had a meningocele projecting into the posterior mediastinum. One of the authors (E. B. K.) observed an intrathoracic meningocele as an incidental finding at the autopsy table.

ETIOLOGY

The frequency with which neurofibromatosis is associated with this type of meningocele is interesting. Hagelstam[9] reviewed the literature and found ninety-four cases of spinal deformity in patients with neurofibromatosis, an incidence of 7 to 20 per cent in the various series reviewed. Most of those were scolioses and kyposcolioses. Only two had spinal nerve root tumors. One of these showed marked erosion of the spinal nerve foramen and the other had eroded the neural arch. No cystic tumors communicating with the subarachnoid space were found. The vertebral defect may be congenital, but a brief survey of textbooks[5, 10, 11, 12] reveals no mention of identical lesions. The projection of the arachnoid on the spinal nerve root through the spinal nerve foramen may be the forerunner of such a cyst.

DIAGNOSIS

The diagnosis can be made fairly easily if one investigates all posterior mediastinal tumors showing abnormalities of the vertebrae with one of the following diagnostic tests:

(1) Air myelography in the lateral decubitus position with the involved side up,

(2) Myelography with suitable radiopaque material in the lateral decubitus position with the involved side down, or,

(3) Drainage of spinal fluid following which a decrease in the size of the cyst should be demonstrable.

TREATMENT

We do not believe this lesion could have caused the patient any real distress and are inclined to believe that the symptoms were suggested only after she was told that she had a tumor within the chest. In the short preoperative stay in the hospital, she was symptomless.

Although this patient apparently has been cured, we are in doubt as to the advisability of operating on this type of lesion unless it shows progressive enlargement or causes symptoms. The defect is difficult to repair satisfactorily and might be associated with a high incidence of recurrence.

SUMMARY

A case of mediastinal meningocele is presented and the operative findings and management are described. The frequent association of this lesion with cutaneous neurofibromatosis and high incidence in women is noted. Although this is a rare lesion, methods of diagnosing mediastinal meningocele without surgical exploration are suggested. It is felt that this is an innocuous tumor which is difficult to cure surgically and that surgical interference is not indicated if the patient is asymptomatic.

REFERENCES

1. Thompson, J. V.: Collective Review, Mediastinal Tumors and Cysts, Internat. Abstr. Surg. 84: 195, 1947.
2. Blades, B.: Mediastinal Tumors, Ann. Surg. 123: 749, 1946.
3. Heuer, G. J., and Andrus, W. D.: The Surgery of Mediastinal Tumors, Am. J. Surg. 50: 146, 1940.
4. Heuer, G. J.: Hourglass Tumors of the Spine, Arch. Surg. 18: 935, 1929.
5. Schmorl, G., and Junghanns, H.: Die Gesunde and Kranke Werbelseule in Rontgenbild, Leipzig, 1939, Georg Thieme, page 122.
6. Pohl, R.: Meningocoele in Brustraum, Röntgenpraxis 5: 747, 1933.
7. Cabello-Campos, J. M.: Foreign Letters, Brazil, Sao Paulo, August 10, 1946, J. A. M. A. 132: 170, 1946.
8. Freedlander, S. O.: Personal Communication, 1946.
9. Hagelstam, Lars: On Deformities of Spine in Multiple Neurofibromatosis, Acta chir. Scandinav. 93: 169, 1946.
10. Keibel, F., and Mall, F. P.: Manual of Human Embryology, Vol. 1, Philadelphia, 1910, J. P. Lippincott Company.
11. Patten, B. M.: Human Embryology, Philadelphia, 1946, The Blakiston Company.
12. Bucey, Paul C.: In Brenneman's *Practice of Pediatrics*, Vol. IV, Chapter XV, Hagerstown, Md., W. F. Prior Company, Inc.

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THE USE OF POLYTHENE FILM IN POSTERIOR THORACOPLASTY WOUNDS

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O. THERON CLAGETT, M.D.,[*] ROCHESTER, MINN.

THOUGH the modern operation of thoracoplasty for permanent collapse of the lung in pulmonary tuberculosis results in closure of cavities and changing the findings in sputum from positive to negative for tubercle bacilli in a large majority of the patients undergoing the multiple-staged operation,[1] efforts to improve the results and to extend the utility of the procedure continue. These efforts must be based on sound judgment in the choice of cases and a complete knowledge of the causes of technical failure. The failure to obtain sufficient collapse for cavitary closure may be due to one or more mechanical factors operating successively or simultaneously; for example, excessive rigidity of the lung and pleura because of extensive inflammatory fibrosis; the presence of partial bronchial obstruction with the development of a "tension" cavity; too rapid regeneration of ribs with fixation of the upper part of the chest wall before the lower supporting ribs can be removed at the next stage; adherence of the soft tissues of the chest wall to the subscapular tissues following resection of the upper two, three, or four ribs. To overcome the mechanical disadvantage presented by excessive rigidity of the lung and pleura various packs and inflatable bags have been proposed: for a "tension" cavity which fails to close after thoracoplasty, cavernostomy and other measures have been tried,[2] to prevent immediate regeneration of the ribs, which interferes with adequate collapse, formalin or Zenker's solution has been applied to the rib bed by many surgeons. It seemed to us that an agent which would prevent adhesion of the chest wall to the subscapular tissues between operative stages, if it were well tolerated by the tissues, might have some logical use in thoracoplasty. Such a substance is apparently available in polythene (polyethylene, a polymer of paraffin). Recently thin sheets of this material have been used beneath the scapula after the first stage of thoracoplasty in three patients at the Mineral Springs Sanatorium, Cannon Falls, Minn. On the basis of this experience no conclusions as to the value of the procedure can be drawn, but the desire to call attention to the possible usefulness of polythene in this manner led us to make this preliminary report.[§]

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[§] The polythene (polyethylene) film used in this study was 0.002 inches thick and was supplied through the courtesy of the manufacturer, the Visking Corporation, Terre Haute, Ind. The manufacturer stated that it contained no impurities.

Fairly extensive experience with the use of polythene in animals has shown that the material is well tolerated by the tissues and that it undergoes no deterioration in the body, even after long periods.[3-6] The behavior of tissue of human beings in contact with the material is similar to that observed in animals. In none of our three patients was there gross evidence of acute inflammatory reaction to polythene that had been buried two weeks and microscopic preparations of specimens from two of them substantiated this observation. In one patient the tissue which had been in contact with the polythene film for two weeks showed no microscopic evidence of inflammatory change, and in the other there was moderate infiltration with lymphocytes. In addition to lymphocytes, a few foreign-body giant cells were present. It is felt, however, that these cells were not due to the presence of the polythene film but to suture material or some other foreign substance introduced at the time of operation. Other studies[3] have shown that polythene produces neither inflammatory nor foreign-body reaction.

REPORT OF CASES

A brief account of the observations made in each case follows:

CASE 1.—A man, aged 38 years, who had moderately advanced tuberculosis of the right upper lobe underwent the first stage of posterior thoracoplasty on Nov. 20, 1946. The first three ribs and half of the fourth rib were removed subperiosteally through a posterolateral incision which permitted elevation of the scapula. The wound surface was sprinkled with sulfanilamide crystals and a sheet of polythene film was fashioned to cover the subscapular surface of the chest wall. At the second stage of the procedure on Dec. 4, 1946, the incision was reopened. Healing had progressed normally. The polythene sheet had prevented the formation of any adhesions between the subscapular tissues and those of the chest wall. There was a moderate collection of serosanguineous fluid in this space, and good collapse of the chest wall had been obtained. Slight edema was present in the tissues of the chest wall which were in contact with the polythene. Subsequent microscopic examination of a section of this tissue revealed mild lymphocytic infiltration and formation of foreign-body giant cells. The wound healed by first intention.

CASE 2.—This patient was a man, aged 28 years, who had a lesion of similar extent to that encountered in Case 1. On Jan. 8, 1947, a first stage thoracoplasty through a posterolateral incision was performed. Three and one-half ribs were removed subperiosteally and sulfanilamide and polythene film were placed in the wound as in the previous case. At the second stage procedure two weeks later, healing was found to be progressing uneventfully. There were no adhesions beneath the scapula and a moderate amount of thin serosanguineous fluid was present in the subscapular space. Some edema of the fascia overlying the erector spinae muscle bundle was noted. There was no gross evidence of acute inflammatory reaction. Histologic study of a small piece of tissue from this patient failed to disclose any inflammatory reaction. A satisfactory collapse was present, and the wound healed without incident.

CASE 3.—This patient, a man 34 years old, had a first stage thoracoplasty on Feb. 5, 1947. The procedure was done in the same manner as it was in the two preceding cases. Again both sulfanilamide crystals and polythene film were placed in the wound immediately before it was closed. The wound healed with no more than the usual reaction in the tissues. At the second stage procedure on Feb. 19, 1947, there was no gross abnormality of the tissues in contact with the polythene, there were no adhesions under the scapula, the usual amount of thin, serosanguineous fluid was present, and a satisfactory depression of the upper part of the chest wall had been obtained. Healing following this procedure was uncomplicated.

COMMENT

We share the view that has been expressed by others[1, 7, 8] that accumulation of fluid beneath the scapula between operative stages is desirable as a compressive force to implement atmospheric pressure and the weight of the tissues in accomplishing the desired collapse of the chest wall. The preservation of a free space beneath the scapula promotes maximal collapse by preventing fixation of the chest wall to the scapula and by permitting the accumulation of a considerable volume of fluid in the subscapular space. Polythene seems to be a material which will permit the attainment of these objectives. As to the reaction observed in the tissues in contact with the material, it is possible that sulfanilamide and suture material may have been at least partly responsible.

SUMMARY

In order to improve the results of modern multiple stage thoracoplasty to produce the permanent collapse of the lung in cases of pulmonary tuberculosis, a number of technical factors must be taken into account. One of these is the interference with collapse that results from the fixation of the upper part of the chest wall to the subscapular tissues by the formation of inflammatory adhesions after the first stage of the procedure. These adhesions can be prevented by the use of a thin sheet of polythene, an inert and apparently completely innocuous material which has been given extensive experimental and a very limited clinical trial. In the three cases which we are reporting, polythene satisfactorily served our purpose. It prevented subscapular adhesions and it did not evoke an objectionable tissue response. So many clinical and technical considerations influence both the clinical and the surgical result of thoracoplasty for pulmonary tuberculosis that no clear-cut decision is likely to be reached about the utility of this procedure. But on the basis of the logic underlying its use, further trial seems worth while.

REFERENCES

1. Alexander, John: The Collapse Therapy of Pulmonary Tuberculosis, Springfield, Ill., 1937, Charles C Thomas, publisher, 705 pp.
2. Maier, H. C.: Surgical Treatment of Tension Cavities in Pulmonary Tuberculosis, Am. Rev. Tuberc. 51: 1-6, 1945.
3. Grindlay, J. H.: Unpublished data.
4. Grindlay, J. H.: Method of Making Tubes of Polyethylene Film for Use in Anastomosis of the Common Bile Duct, Trachea, and Pelvic Colon, Surgery 24: 22-29, 1948.
5. Grindlay, J. H., and Gray, H. K.: Molded Plastic Tubes: An Experimental Study With Especial Reference to Their Use in Reconstruction of the Common Duct. (Unpublished data.)
6. Brown, M. H., Grindlay, J. H., and Craig, W. McK.: The Use of Polythene Film as a Dural Substitute: A Preliminary Report, J. Neurosurg. 4: 505-507, 1947.
7. Cory, R. A. S.: Report of a Clinical Trial of Oxidized Gauze in Seven Thoracoplasties, J. Thoracic Surg. 15: 261-265, 1946.
8. Hedberg, G. A.: Personal communication to the authors.

BRONCHIOGENIC CYST OF THE MEDIASTINUM

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IN RECENT years more has become known about the bronchiogenic cysts of the mediastinum, but observation and treatment of such cases is rare. From the publications of Blades and of Adams and Thornton most cases are asymptomatic and are found through examination by x-ray of groups of people, as in the army and navy.

At the present time the opinion is that tumors and cysts of the mediastinum should be removed, even though they cause few or no symptoms, as there is always the danger of future complications. Since this opinion has become more general, there is a marked increase in number of the operations performed (Blades). In 1937 reports of 8 cases were published by Alford. In 1940 Heuer and Andrus quoted 25 cases to which they added one of their own. In 1945 Laipply brought the number of known cases to 34. Finally in 1946 Blades reported upon 23 patients who had been operated upon in different thoracic surgery departments of the United States Army.

The first surgeon who treated a bronchiogenic cyst with success in Holland was Nyst. The cyst was found in a woman 20 years old, who had dysphagia for several years. The complaints increased, but after removal of the cyst by means of an anterior superior longitudinal mediastinotomy, according to Sauerbruch, her complaints disappeared.

In 1946 Eerland performed a successful transthoracic operation upon a woman 33 years of age. Before the operation the patient had suffered from fatigue, pain radiating from the shoulders to both arms, and attacks of dyspnea.

In 1943 we treated a bronchiogenic cyst and the case is reported here.

CASE REPORT

On Dec. 31, 1942, a 6-year-old girl was admitted to the Juliana Children Hospital and the case was diagnosed as bronchopneumonia with cavity in the right lung. She had had pertussis some years prior to this and afterward repeated attacks of bronchitis. Ten days before admission to the hospital she was ill with high temperature, spells of coughing, and dyspnea. Two days before admission the condition had grown much worse in spite of chemotherapy. She expectorated a greenish mucopurulent secretion, lost her appetite, and became emaciated. There was no tuberculosis in the family.

On examination the child was found to be short of breath and cyanotic. The mucous membranes were cyanotic. There was no jaundice and no evidence of anemia. Lymphatic glands were palpable in the groins. The turgor of the skin was good. The condition of the heart was normal. In the lungs only bronchitic murmurs were audible. The abdomen and limbs were normal. The temperature fluctuated between 39 and 40° C. The pulse frequency was 140-160, but regular. Upon examination the greenish mucopurulent sputum showed no

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tubercle bacilli. Urine was normal. The blood sedimentation rate was 55 after one hour, 75 after two hours. Red blood count on admission was 4,000,000 with hemoglobin 90 per cent; the white blood count 21,400 (6 per cent stab neutrophilic, 80 per cent segmented neutrophilic, 11 per cent small lymphocytes, 2 per cent monocytes, and 1 per cent basophilics). The thrombocytic count was normal.

An x-ray picture of the chest showed a shadow in the right lower lobe, probably of pneumonic or pleuritic origin. In the upper part of the chest a sharply outlined density, the size of a goose egg, protruded from the mediastinum to the upper lobe. The oblique x-ray view showed compression of the trachea directly above the bifurcation. The right main bronchus was also compressed, though less than the main bronchus (Fig. 1). On a bronchogram with lipiodol there was no bronchiectasis in the right lung.

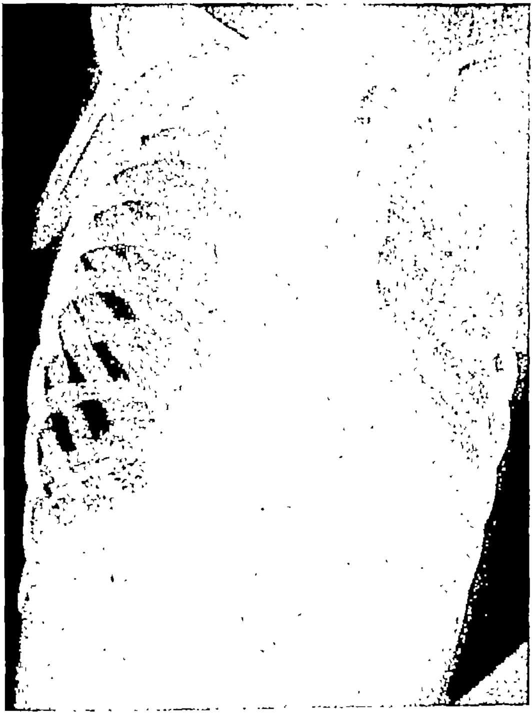

Fig. 1.—Compression of the trachea (oblique x-ray) directly above the bifurcation: compression of the right main bronchus.

On the basis of the x-ray examination it was decided that the tumor of the mediastinum was benign (dermoid cyst). Through the compression of the trachea and the right main bronchus, the tumor caused repeated attacks of retention in the right lung with symptoms of pneumonia. Surgery was indicated.

Operation.—Operation was performed on Jan. 8, 1943 (J. E.). Nitrous oxide oxygen-ether anesthesia was administered after premedication with atropine (¼ mg.) and rectidon.

thin-walled blood vessels. In the connective tissue there was infiltration of lymphocytes, plasma cells, and polymorphonuclears. A small area of mucous glands of very regular structure was found in the deeper layers. The protoplasm of these glands was slight vacuolar.

In the more solid part (lump) there were three bent pieces of cartilage (Fig. 3). The cartilaginous tissue was of a regular structure and surrounded by perichondrium. In the small interspaces between the ends of the cartilages there were many mucous glands extending behind the cartilages. There was no muscle tissue (Fig. 4).

Conclusion was bronchiogenic cyst of the mediastinum.

Chemistry of the cystic fluid: The test of Rivalta with 10 times diluted cystic fluid gave negative findings. The undiluted liquid was too viscous to test it in any other way. The test of Benedikt with 10 times diluted fluid revealed negative findings. After boiling the fluid with an equal volume 5 per cent HCl, the test of Benedikt was slightly positive.

The fluid diluted 1:15 with acetic acid in cold air gave a bubbling. The Kjeldahl test with 75 times diluted liquid: total nitrogen, 40.50 per cent; nonprotein nitrogen, 17.25 per cent; protein nitrogen, 23.25 per cent; total protein, 14.50 per cent; phosphorus, 98 mg. per cent.

REFERENCES

Alford, J. E.: Congenital Bronchiogenic Cyst of the Mediastinum, J. Pediat. 11: 550, 1937.

Blades, B.: Mediastinal Tumors, Ann. Surg. 123: 749, 1946.

Eerland, L. D.: Bronchogene cyste van het mediastinum, Nederl. tijdschr. v. geneesk. 90: 1295, 1946.

Heuer, G. J., and Andrus, William DeWitt: The Surgery of Mediastinal Tumors, Am. J. Surg. 50: 143, 1940.

Laipply, T. C.: Cysts and Cystic Tumors of Mediastinum, Arch. Path. 39: 153, 1945, cited by Eerland.

Nyst, P. M. E. Ph.: Aangeboren bronchogene cyste van het mediastinum, Nederl. Tijdschr. v. geneesk. 85: 1809, 1941.

Adams, W. E., and Thornton, T. F.: Bronchiogenic Cysts of the Mediastinum, J. THORACIC SURG. 12: 503, 1943.

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Original Communications

THE MALIGNANT NATURE OF BRONCHIAL ADENOMA

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WESSLER and Rabin,[1] in 1932, reported the separation of bronchial adenoma from bronchiogenic carcinoma, and they pointed out that some of these tumors became malignant. By 1941 we[2] had reported eighteen cases of bronchial adenoma and stated that these tumors exhibited growth potentials midway between distantly metastasizing carcinomatous and purely local polypoid bronchial tumors. In these publications clinical and pathologic manifestations were discussed.[3, 4] Treatment was concluded to include bronchoscopic removal in certain instances but sooner or later because of the growth of the extrabronchial portion or suppuration in the distal lung, pulmonary resection was indicated. Subsequently a personal experience with approximately fifteen additional cases has confirmed the previously reported findings. However, during the past few years the publications by Womack and Graham,[5] Anderson,[6] Chamberlain,[7] and Crafoord[8] have served to emphasize the potential malignant qualities inherent in these tumors. In 1947 I[9] published follow-up results of operated cases.[9] Six of these ten patients had survived more than five years since operation without appearance of any distant metastases or spread. By now, two additional patients of this group have passed the five-year mark, giving 80 per cent so-called five-year cures.

It was always stated that this subject although greatly clarified is still somewhat obscure, because some varieties of bronchial adenoma may be more malignant than others (Brunn[10]). The recent report of the Army Institute of Pathology[11] has shed some light on the question of varieties of bronchial adenomas. A histologic division into predominantly carcinoid and mixed tumor type has been described, and the mixed tumor type is probably more apt to exhibit greater degrees of malignancy.

From the Thoracic Surgical Services of the Cedars of Lebanon Hospital, Los Angeles, and the Birmingham Veterans Hospital, Van Nuys.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

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During the past two years observations have been made upon an additional unreported group of patients which tend to indicate that a high degree of malignancy may be exhibited by bronchial adenoma, especially of the mixed tumor type, until at post-mortem bronchiogenic carcinoma rather than mixed tumor type of bronchial adenoma is diagnosed. Womack and Graham[5] had indicated that such a malignant transformation from so-called benign bronchial adenoma could occur. This first case to be reported is the only one of approximately forty cases where such a high degree of malignancy did occur and is one of two cases observed, both of the mixed tumor type and both of which ended in death. In each, endoscopic and radiation treatment without pulmonary resection resulted in recurrence of the tumor located at the bifurcation of the trachea.

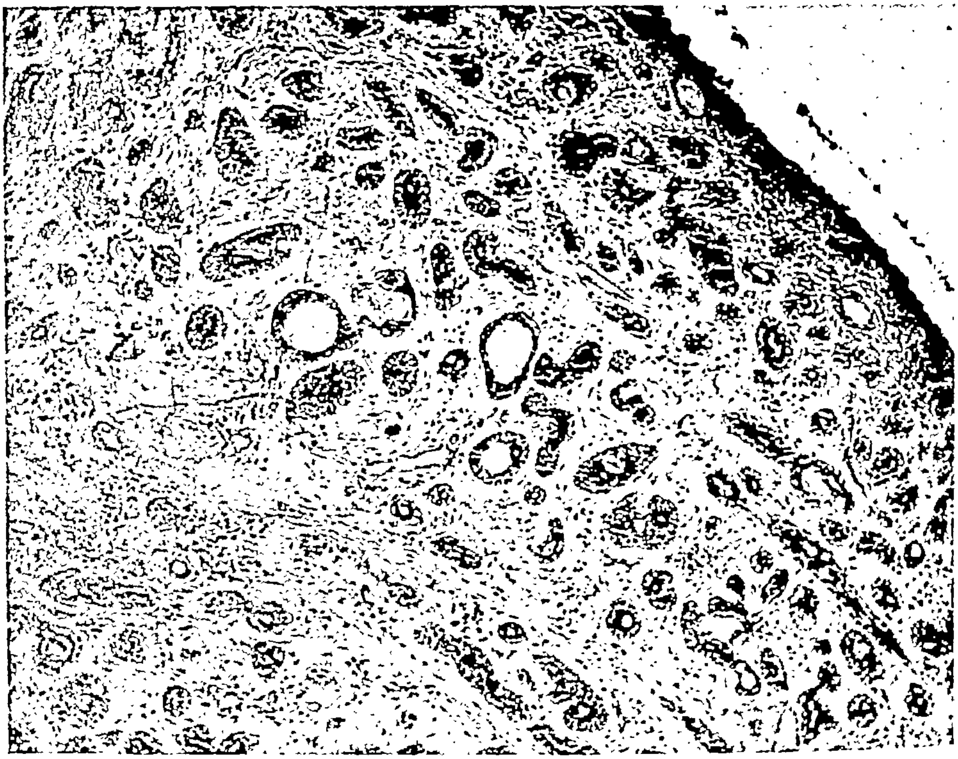

Fig. 1 (Case 1).—Bronchoscopic biopsy April 14, 1942, E. S. Note the mixed tumor pattern from the tumor of the lower end of the trachea. (Microphotograph ×85.)

Case 1.—E. S. (DA-22-48), a white man, aged 58 years at the time of death, first entered the Cedars of Lebanon Hospital April 14, 1942, with complaints of asthma, chronic bronchitis, and hemoptysis. Bronchoscopy was done on this date and a biopsy was taken from a nickel-sized polypoid tumor at the lower end of the left wall of the trachea which occluded the trachea to approximately one-fifth of normal. The bronchoscopic biopsy was reported as bronchial adenoma. Fig. 1 shows this biopsy, and the fact that it conforms to the mixed tumor type of bronchial adenoma was confirmed. During the next year several bronchoscopic examinations were made with cauterization; radon and x-ray therapy were administered. Subsequent bronchoscopic examinations up to January, 1944, disclosed only little tumor remaining. Dyspnea became progressively worse in 1945 and 1946, requiring several emergency bronchoscopies at which time very little tumor tissue was noted but the left stem bronchus was narrowed to 50 per cent of normal as well as the trachea, and purulent secretions were aspirated. In 1947 the tumor mass was more prominent and cauterization was again resorted to. However, attacks of tracheal suffocation and severe dyspnea continued. With the idea of performing a left pneumonectomy and local resection of the tumor, exploratory thoracotomy was performed on Nov. 21, 1947. Shortly after the left pleural cavity was entered, the anesthetist announced that he was unable to aerate the patient's lungs through the intratracheal tube. The lower end of the trachea was rapidly exposed and an incision was made in the anterior wall of the last centimeter of the trachea. Through this a No. 20 French catheter was passed into the right stem bronchus and oxygen was administered followed by improvement in the patient's condition. From the center of this transverse tracheotomy another incision was made inferiorly for 3 cm. into the left stem bronchus. The edges of this incision were approximated to the proximal edge of the transverse tracheotomy and the anesthetist announced that better aeration was established. The catheter was then removed and adequate oxygenation was carried on as the result of the "Tee" plastic procedure performed. Additional findings were pleural implants from 1 to 5 mm. in diameter, infiltration of esophagus and trachea, and suppuration of the left lower lobe. The postoperative course was fairly smooth, neither tracheopleural fistula nor empyema developed. He was discharged on the fourteenth postoperative day but returned with acute tracheal obstruction six weeks later, and was relieved by bronchoscopic aspiration only to succumb to another attack after three weeks.

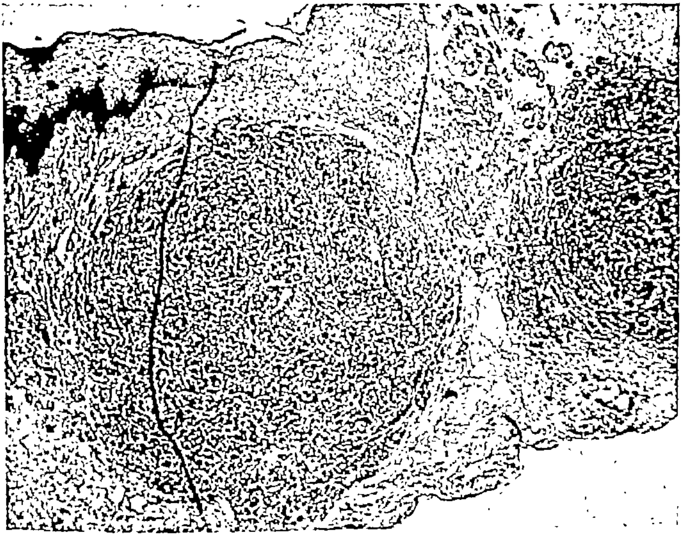

Fig. 2 (Case 1).—Post-mortem specimen, E. S. Metastatic nodule invading esophagus. (Microphotograph ×35.)

Post-mortem examination showed carcinoma of trachea with invasion of the upper trachea, esophagus (Fig. 2), mediastinum, and metastases to pericardium, lungs, left parietal pleura, adjacent lymph nodes, and prevertebral fascia of the neck (Fig. 3). Microscopic examination showed not only the "Swiss cheese" mixed tumor appearance of some areas of the malignant tumor but also areas of frank malignant cells (Fig. 4). There seemed little

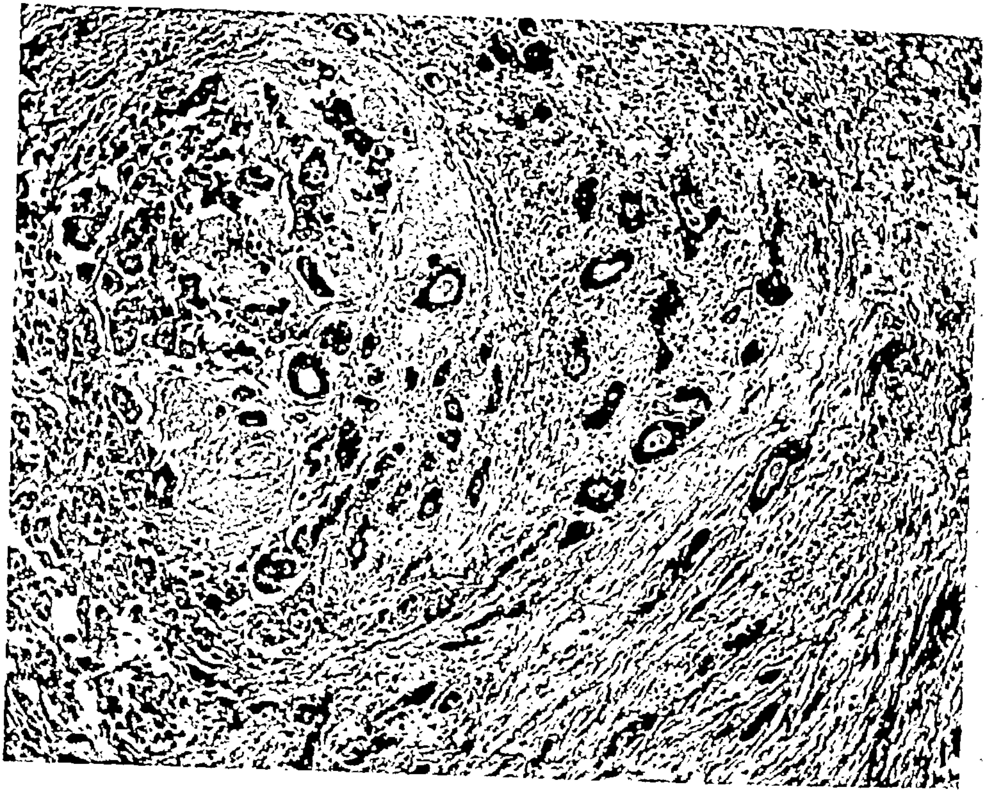

Fig. 3 (Case 1).—Post-mortem specimen, E. S. Note the tendency to reduplicate the mixed tumor pattern seen six years before in the bronchoscopic biopsy. (Microphotograph ×85.)

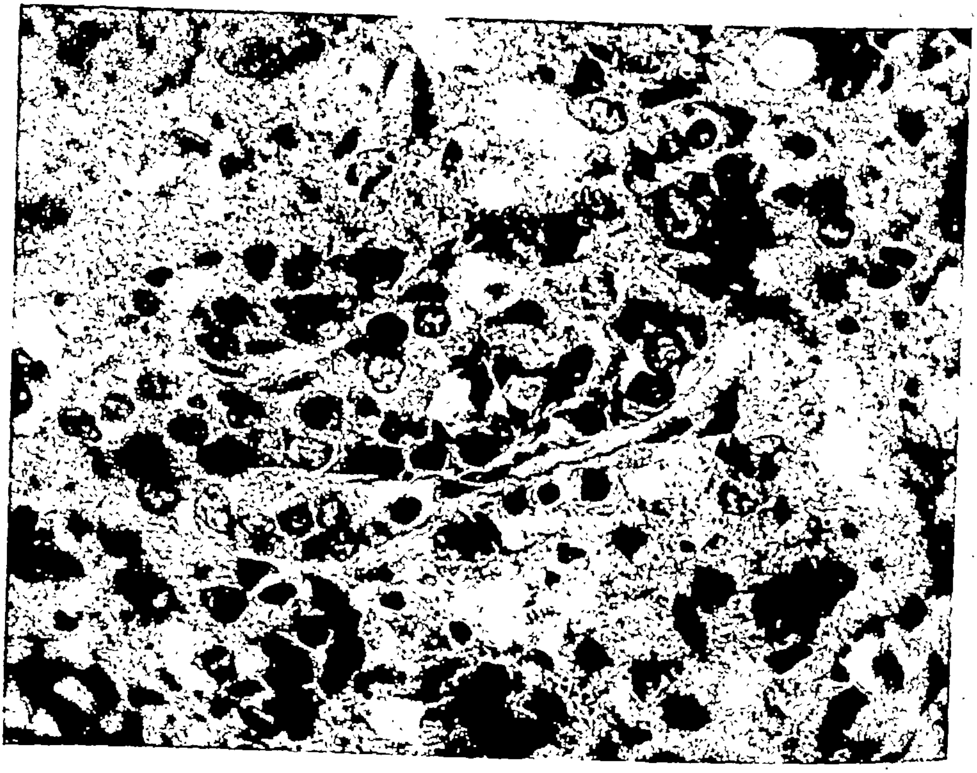

Fig. 4 (Case 1).—Post-mortem specimen, E. S. Note numbers of frank malignant cells with large irregular nuclei. (Microphotograph, ×450.)

doubt that a mixed tumor type of bronchial adenoma had become, in approximately six years of treatment and observation, a highly malignant carcinoma. Nor is there much doubt that if this neoplasm were seen only at post-mortem (without the 1942 biopsy, Fig. 1) it would have been diagnosed as an undifferentiated carcinoma of bronchiogenic origin.

The significance of this case may be that certain bronchiogenic carcinomas, particularly those of long duration[12] had their origin in a bronchial adenoma. It is urged that all bronchial adenomas continue to be observed for malignant transformation.

The following cases illustrate less severe degrees of malignancy, especially invasiveness and local metastases.

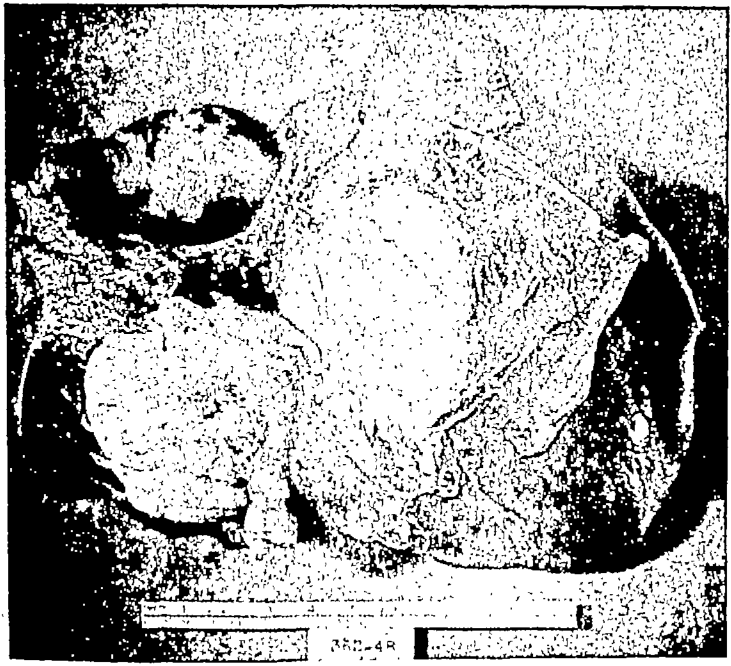

Fig. 5 (Case 2).—Surgical specimen, right lower, right middle lobes, K. F. Note the large size of the tumor in spite of the short history.

CASE 2.—K. F. (S-362-48), a white woman aged 30 years, was admitted to the Cedars of Lebanon Hospital, Jan. 25, 1948, referred by Doctor J. M. Krevett. Onset of symptoms was Dec. 1, 1947, with persistent cough, weakness, and pain in the right chest. X-ray films of the chest showed a tumor mass in the right lower lobe. Bronchoscopic examination was performed January 26, 1948, with findings of a bronchial adenoma obstructing the bifurcation of the right stem bronchus at the take-off of the right middle lobe. Right middle and lower lobectomy was performed on Jan. 29, 1948. The tumor was 7 cm. in its greater diameter (Fig. 5), invaded through bronchial walls about the inferior pulmonary vein, and involved a neighboring lymph node by contiguous spread (Fig. 6). Very little distal bronchiectasis was present. Microscopic examination showed the characteristic "Swiss cheese" (Fig. 7) pattern of the mixed tumor type of bronchial adenoma. The patient was discharged on the tenth postoperative day and has remained symptom-free these past five months.

The microscopic appearance with the invasiveness and large size together with the short duration of symptoms (two months) all indicate a more rapidly growing tumor than is usually expected with the carcinoid type of bronchial

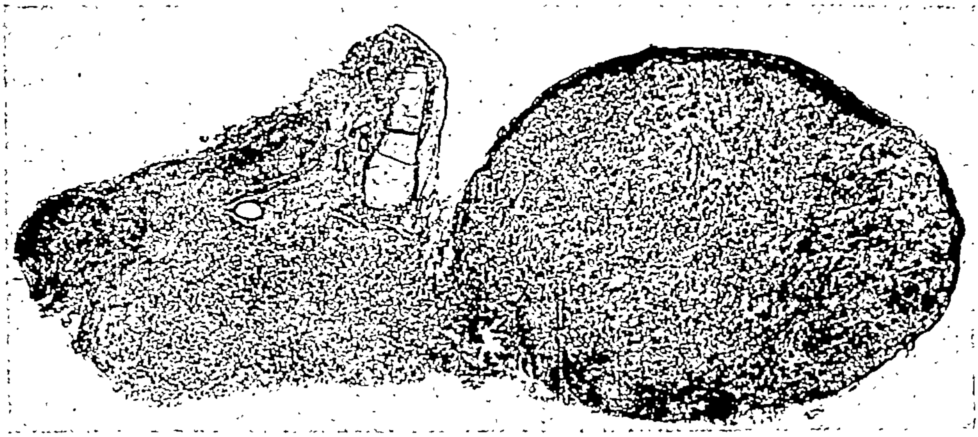

Fig. 6 (Case 2).—Surgical specimen, K. F. Note the invasion through the bronchial wall of adenoma of the mixed type and the invasion of neighboring lymph node by contiguity. (Microphotograph, ×6.)

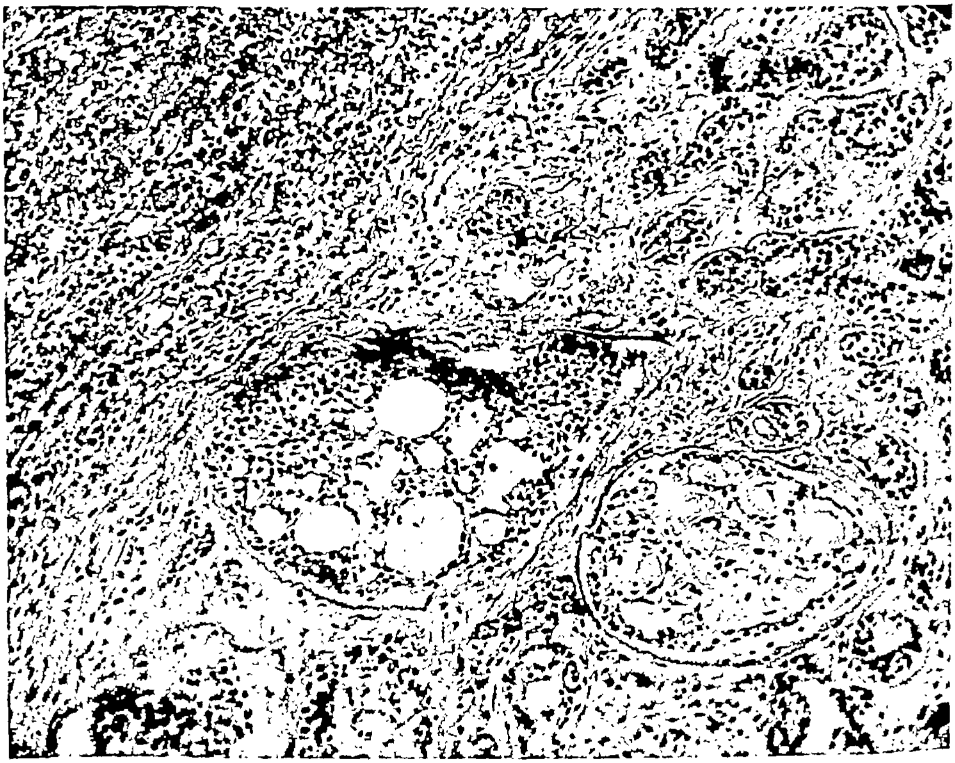

Fig. 7 (Case 2).—Surgical specimen, K. F. Note the "Swiss cheese" appearance found in the mixed tumor type of bronchial adenoma. (Microphotograph, ×125.)

adenoma. No areas of malignant transformation such as seen in Case 1 were present, but one wonders if this tumor were allowed to remain whether more malignant features would have developed. Also the future might well show that it would have been better to have performed total pneumonectomy instead of right lower and middle lobectomy. It is urged that patients treated with only lobectomy be carefully followed for recurrence and metastases, especially if they are microscopically of the mixed tumor type.

The next two cases are bronchial adenomas of the carcinoid type of extremely long duration and occurring together with neoplasms arising independently in other organs of the body. In both these patients local invasion but not distant metastases occurred.

CASE 3.—L. B. (S-1430-47), a 60-year-old man, entered Birmingham Veteran's Hospital on March 10, 1947, complaining of weakness, fatigue, and cough productive of mucopurulent sputum. He had a history of frequent respiratory infections from 1917 to the time of admission. There was a hemoptysis in 1922 and since that time there had been intermittent subsequent pulmonary hemorrhages, often lasting several days and of a pint or more. He was hospitalized on many occasions between 1922 and 1947 and given the various diagnoses of pneumonia, lung abscess, and empyema. He had the diagnosis of pneumonia on four different occasions. In July, 1933, a right phrenicectomy was performed and two months later a right thoracotomy was done to drain an empyema. Following this, the patient's symptoms were markedly improved but a chronic draining chest wall sinus continued to drain for the next fourteen years. Communication with the bronchial tree was established and chronic lung abscess with bronchocutaneous fistula was diagnosed.

Chronic lymphatic leucemia was diagnosed in 1943 at the San Diego Naval Hospital. White blood counts as high as 160,000 per cubic millimeter were reported. Fatigue and lassitude were the main symptoms on entry.

Past History.—There had been no serious diseases.

Family History.—There was no history of tumor or cancer in the family but the patient's mother had died in middle age of what possibly was pulmonary tuberculosis.

Examination.—Physical examination revealed a thin, pale, chronically ill appearing 60-year-old white man. There was an old healed 10 cm. thoracotomy scar in the right posterior axillary line. A small "pencil-point" draining sinus was present in the seventh interspace. There were fine moist râles in the right apex and dullness over the entire right lower and middle lobes. A permanent right diaphragmatic paralysis was present.

Laboratory Findings.—X-ray views of the chest showed elevation of the right diaphragm, regenerated eighth rib, deviation of the trachea to the right, and probable shrinkage of the right lower and middle lobes. Subsequent x-ray films and planigrams demonstrated a large mass in the paramediastinal area of the right lower part of the chest. Examination of the blood revealed normal red count and hemoglobin, white blood count 60,300, 71 per cent lymphocytes, 27 polymorphonuclear leucocytes, and 2 monocytes. Bone marrow puncture of the sternum, March 27, 1947, showed lymphatic hyperplasia of the bone marrow characteristic of subacute lymphatic leucemia and many pro-lymphocytes were present.

Bronchoscopy was done on the patient for the first time March 19, 1947, which revealed a bosselated mass in the right main stem bronchus 1 cm. below the carina, completely occluding, and covered with a grayish removable exudate. First biopsies showed only necrotic tissue. One week later *bronchial adenoma* with extensive necrosis was diagnosed from the biopsy. Bronchial smears made at this bronchoscopy were positive for tubercle bacilli.

Pyuria and hematuria developed in April and cystoscopically a transitional cell carcinoma of the bladder was fulgurated and removed. Repeat bronchoscopy July 22 showed no essential change. More tumor was removed for study. On Sept. 12, 1947, a transurethral resection of the prostate was performed for obstructive uropathy. Microscopic examination of the prostatic tissue was benign prostatic hyperplasia. An acute tuberculous pneumonitis appeared in the previously clear right upper lobe at this time.

The bladder carcinoma was now under control and the patient was prepared for a right pneumonectomy with the aid of streptomycin. On Oct. 15, 1947, a right pneumonectomy was performed. Surgical specimen showed a large tumor, not only in the right stem bronchus, but also invading toward the mediastinum. There were several enlarged lymph nodes in the mediastinum from 1 to 3 cm. in size. One of these showed a fairly acute tuberculous process. The postoperative course was relatively uneventful. One month following the pneumonectomy a partial thoracoplasty was performed to protect against overexpansion of the left lung. Recovery following this operation was uneventful.

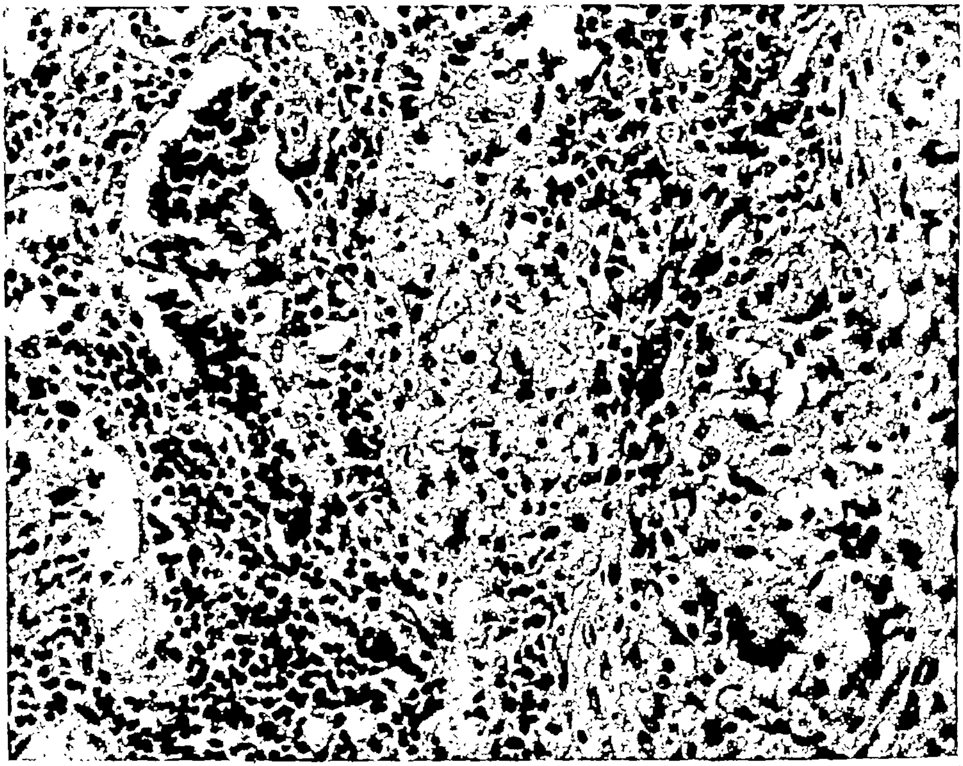

Fig. 8 (Case 3).—Surgical specimen, L. B. Note the Langhans' giant cells and the adjacent invading bronchial adenoma. Bronchial adenoma invading tuberculous lymph node. (Microphotograph, ×200.)

The measurements of the tumor were 3.75 by 6.25 cm. Large blood vessels were compressed by the tumor. Several acute tuberculous nodules were seen close to the pleura on cut section of the lung. In one area the tumor invaded by contiguity a tuberculous lymph node (Fig. 8). Microscopic sections of the tumor showed the pattern to be consistent with carcinoid type of adenoma. Another lymph node showed a clump of tumor cells attached to the capsule, and a third lymph node showed small masses of tumor cells in the capsule and invading the parenchyma of the lymph node. A diagnosis was bronchial adenoma with metastases to surrounding lymph nodes and fibrocaseous tuberculosis, with acute dissemination.

Five months after the thoracoplasty a series of 20 negative sputum smears and cultures had been obtained, and 110 days of streptomycin treatment had been completed. The patient was discharged home with maximum hospital benefits. At the time of discharge the white blood count was 73,000 but it had dropped as low as 15,000. Cystoscopies showed no further evidence of the carcinoma of the bladder.

This case illustrates the malignant nature of the carcinoid type of bronchial adenoma that is associated with pulmonary suppuration for approximately thirty years. Only local invasion of mediastinum lymph nodes has occurred. The interesting features of concomitant presence of chronic lymphatic leucemia, transitional carcinoma of the bladder, and pulmonary tuberculosis are difficult to tie up in any clinical pattern. These findings together with a bronchial adenoma suggest that the origin of a bronchial adenoma may occur from the same stimuli that produce tumors in general in the body. It is of still greater interest that all of the three neoplastic disturbances in this one patient were relatively benign, in spite of the microscopic malignancy. It would appear that the carcinoid form of bronchial adenoma takes on a much more benign course clinically than the more malignant mixed tumor form of bronchial adenoma.

CASE 4.—L. S. (DA-4-48), a white woman 46 years of age at the time of death, was admitted to the Cedars of Lebanon Hospital Dec. 30, 1947. Thirty years before entry she had had a right empyema which was drained and ever since that time had a persistent draining sinus of the chest wall. Bronchoscopies had been performed as long ago as twenty years and a lesion in the right stem bronchus had been described. Approximately ten years before, a positive biopsy for a bronchial adenoma was obtained. General condition though not good allowed her to carry on a fairly normal existence until 1946 when she began to develop symptoms of an intracranial lesion. A pituitary adenoma was later diagnosed, and when she entered on this admission, she suffered from severe headaches, faintness, visual blurring, staggering and instability of equilibrium, as well as dyspnea, orthopnea, and palpitation. On physical examination she was found to have coarse skin, large tongue, hypertrichosis, absence of breath sounds in the right base, with râles on cough. Blood pressure showed a mild hypertension. X-ray therapy had been given one year before to the pituitary, and on entry x-ray examination of the skull showed erosion and enlargement of the sella turcica. Following entry, her condition remained poor and became critical one week after entry, she died Jan. 6, 1948.

The post-mortem examination showed 2 cm. from the main stem bronchus on the right a large adenoma which measured approximately 3 cm. in its greatest diameter. There were two large cystic cavities distal to the obstruction caused by the adenoma. These were approximately 4 cm. in diameter. The bronchial adenoma invaded through the wall of the right stem bronchus and the extrabronchial portion measured 7 cm. in greatest diameter. The fistulous tract communicated with the bronchi and the skin of the thoracoplasty scar. There were several enlarged mediastinal lymph nodes. There were bilateral adenomas of the adrenal glands, cor pulmonale, mixed adenomas of the pituitary gland with proliferation of all three cell types, early malignant transformation, and persistent large pineal gland. Microscopically, the tumor was of the carcinoid type and some granules in the cytoplasm could be demonstrated with argentaffin staining. Invasion of the mediastinal lymph nodes and the adventitia of the pulmonary artery were demonstrated, and in another section a dumbbell mushrooming of the adenoma into a large pulmonary vein was noted (Fig. 9).

This case demonstrates vascular invasion, as well as mediastinal lymph node invasion, in a carcinoid type of bronchial adenoma of over thirty years' proved duration. The concomitant adenomas of the adrenals and pituitary gland suggest again that whatever stimulus produced the bronchial adenoma stimulated other organs to produce adenomatous growths in them. Again, the low-grade invasion of the carcinoid type of bronchial adenoma is demonstrated. In spite of definite evidence of invasion into the lumen of a large pulmonary

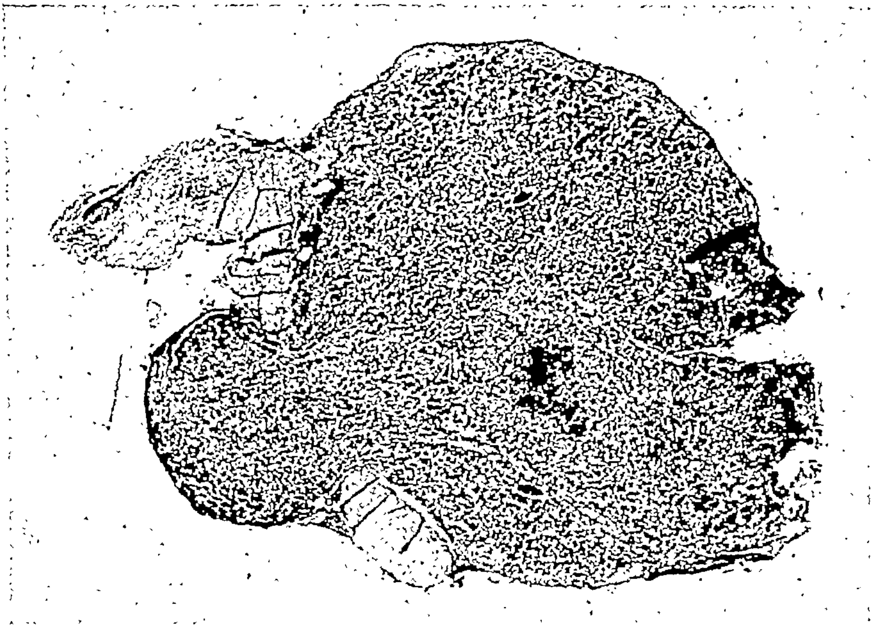

Fig. 9 (Case 4).—Post-mortem specimen, L. S. Note the mushrooming of the bronchial adenoma through the vein wall. In spite of tumor floating in the lumen of the vein no vascular seeding of bronchial adenoma could be found. (Microphotograph ×6.)

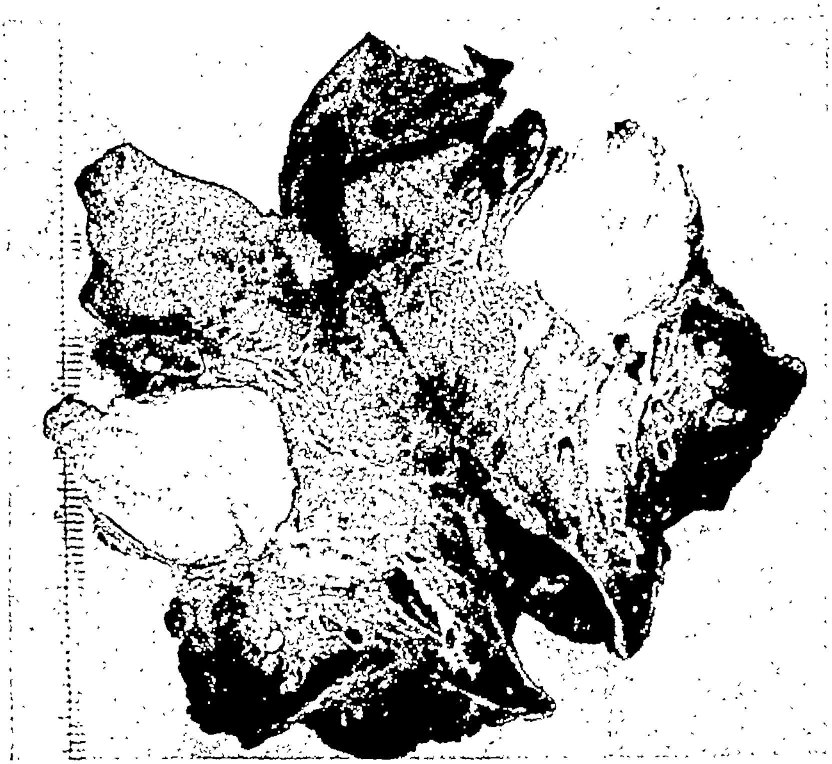

Fig. 10 (Case 5).—Surgical specimen left lower lobe, A. K. Note the metastatic nodule in the lymph node close to the large adenoma.

vein, no metastatic vascular seeding was demonstrated. This suggests that the environment favoring growth of bronchial adenomas of this type is found in the bronchus and not elsewhere in the body. The relatively small growth found in the metastatic lymph nodes also favors this point of view. Adenoma which invades lymph nodes has not been observed to reach the proportions commonly found with bronchiogenic carcinoma when it invades lymph nodes.

CASE 5.—A. K. *(Registry No. 2103), a white man, aged 25 years, first entered the* Birmingham Veteran's Hospital Aug. 23, 1946. Onset of symptoms was two months before, with a pneumonia. Bronchoscopy was first performed October 3 with the findings of a polypoid tumor attached to the medial wall of the left lower lobe bronchus and bronchiectasis. Bronchoscopic biopsy was *bronchial adenoma, carcinoid type. X-ray films confirmed the presence* of a tumor mass. Lobectomy of the left lower lobe was performed Oct. 29, 1946. The specimen removed revealed a large ulcerated adenoma of the bronchus attached at the base of the markedly dilated left stem bronchus completely obstructing it. There was marked invasion of the adenoma through the bronchial wall into the adjacent lung parenchyma and what appeared to be a recent increased rate of growth associated with this extension through the bronchial wall. Two small recent metastases to peribronchial lymph nodes were demonstrated (Fig. 10). Microscopically, the tumor was of the carcinoid type and it is noteworthy that at the base of the tumor where it was attached to the bronchial wall there were a large number of stellate type of cells. The tumor that appeared beyond the bronchial wall was somewhat different although the general pattern was retained. These cells were larger, the cytoplasm more pale-staining, and the nuclei varied distinctly in size, some of them being fairly large and hyperchromatic. Mucicarmine stains revealed no mucous production by the cells. X-ray pictures were later made of all of the bones of the body and no metastatic lesions were seen. Electroencephalogram suggested some abnormality of the cerebral cortex but nothing clinical could substantiate these findings. One year after operation the patient was heard from by mail and was apparently well

This represented apparently a carcinoid bronchial adenoma with fairly early metastases to regional lymph nodes and a short duration of symptoms. Lobectomy was done although metastatic tumor occurred in the mediastinal lymph nodes of the hilum of the left lower lobe. The follow-up on this patient will be watched with keen interest.

SUMMARY AND DISCUSSION

Five patients showing malignant qualities in bronchial adenomas are reported. The most malignant changes to occur were found in the mixed tumor type of bronchial adenomas. The complete transformation to a clinical and histologic picture of bronchiogenic carcinoma has been observed and is reported herein. It is suggested that *carcinoma of bronchiogenic origin may at times* arise in a mixed tumor type of bronchial adenoma. Carcinoid types of bronchial adenoma not infrequently show metastatic involvement of the mediastinal lymph nodes. Observations are presented which indicate that this may occur when the tumors have been present for as long as thirty years or when the duration of symptoms is only a few months. The finding of bronchial adenoma in conjunction with multiple tumors of low-grade malignancy in other organs suggests that the stimulus for the production of *bronchial adenoma is the same as that* capable of producing neoplasms in other organs than the lung. The failure of bronchial adenoma to produce vascular seedings even though the tumor cells were demonstrated floating in the lumen of a large pulmonary vein suggests that the only favorable soil for bronchial adenoma is in the bronchi and lung.

The treatment of bronchial adenomas by lobectomy and pneumonectomy has given approximately 100 per cent five-year cures where this period of time has elapsed since operation. From the observations on tumors of over thirty years' duration it would appear that several decades will be necessary to observe patients treated by lobectomy and pneumonectomy before the recurrence rate can be definitely established. The malignant nature of bronchial adenoma is not so malignant nor is its benign course so benign.

REFERENCES

1. Wessler, H., and Rabin, C.: Benign Tumors of the Bronchus, Am. J. M. Sc. 183: 171, 1932.
2. Brunn, H., and Goldman, A.: The Differentiation of Benign From Malignant Polypoid Bronchial Tumors, Surg., Gynec. & Obst. 71: 703-722, 1940.
3. Goldman, A., and Stephens, H. B.: Polypoid Bronchial Tumors, J. Thoracic Surg. 10: 327-353, 1941.
4. Brunn, H., and Goldman, A.: Bronchial Adenoma, Am. J. Surg. 44: 179-192, 1941.
5. Womack, N. A., and Graham, E.: Mixed Tumors of the Lung, Arch. Path. 26: 195, 1938.
6. Anderson, W. M.: Bronchial Adenoma With Metastasis to the Liver, J. Thoracic Surg. 12: 351, 1942.
7. Chamberlain, J. M., and Gordon, J.: Bronchial Adenoma Treated by Pulmonary Resection, J. Thoracic Surg. 14: 144, 1945.
8. Crafoord, C., and Lindgren, A. G. H.: Mucous and Salivary Gland Tumors in the Bronchi and Trachea, Formerly Generally Called Bronchial Adenoma, Acta chir. Scandinav. 92: 481-506, 1945.
9. Goldman, A.: The Surgical Treatment of Bronchial Adenoma, Dis. of Chest 13: 321, 1947.
10. Brunn, H.: Quoted by Goldman, A.: The Surgical Treatment of Bronchial Adenoma, Dis. of Chest 13: 321, 1947.
11. Holley, S. W.: Bronchial Adenoma, Mil. Surgeon 99: 528-554, 1946.
12. Goldman, A.: Carcinoma of the Lung of Long Duration, Medico-Surgical Tributes to Harold Brunn, University of California Press, Berkeley, 1942.

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(See discussion on page 155.)

ADENOMA OF THE BRONCHUS

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THE first report from the Mount Sinai Hospital of the features of a group of cases of bronchial adenoma was made by Wessler and Rabin in 1932. At first there appeared to be general acceptance of the views which were expressed concerning pathology and treatment. In the original paper involvement of the tissues beyond the bronchial wall was described in two cases. Malignancy of bronchial adenoma has been emphasized to such an extent in recent years that the prevailing opinion at the present time appears to be, first, that the tumor cannot be removed completely bronchoscopically and, second, that surgical eradication should comprise the sole treatment as in the case of cancer of the lung. Whereas some regard the lesion to be actually malignant, others believe that radical treatment alone is permissible because of potential malignancy.

Before general consideration of the subject, the microscopic features of bronchial adenoma should be described. The tumor consists of small cells with regular round or oval nuclei and rare, if any, certain mitoses. Nucleoli are inconspicuous. The cells are either cuboidal, cylindrical, or polyhedral and the cytoplasm is usually scanty and may be entirely clear. The cells are generally arranged in groups, separated by a fine stroma, but in places this may be thick and hyalinized. In these locations, the nuclei are often elongated and may be irregular nad pyknotic, suggesting carcinoma. The same irregular and pyknotic appearance may occur at the periphery of the biopsy specimen, where the tissue has been crushed by bronchoscopic forceps and may also cause an error in diagnosis if the regularity of the nuclei in the center of the specimen is not appreciated. True gland formations are rare. However, the occurrence of glandlike formations is not uncommon.

The only two types of carcinoma that may be simulated are adenocarcinoma and small round or oat cell carcinoma. Adenocarcinoma of the bronchus is composed of large cells in contrast to those of bronchial adenoma. The real difficulty lies in the differentiation from small cell carcinoma. The presence of many mitoses, which is characteristic of small round or oat cell carcinoma, will decide the diagnosis in most instances. The difficulty in differentiation from the occasional case of small cell carcinoma with regular nuclei and with rare or absent mitoses can usually be resolved by a study of the arrangement of the cells and their relationship to the stroma. If the cells are arranged in gland formations, the diagnosis of small cell carcinoma may be excluded. Furthermore, the cells in small cell carcinoma are distributed in

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From the Mount Sinai Hospital.

irregular masses without definite arrangement in relationship to the stroma. The mosaic-like alveolar pattern, with groups of cells separated by a fine stroma, is not seen in small cell carcinoma. In the absence of glandlike formations or of a solid alveolar pattern, the arrangement of the cells in the form of double rows or palisades separated by linear fine stroma will also serve to differentiate adenoma from small cell carcinoma. Infiltration or the appearance of infiltration of the stroma has, in the past, led to confusion with carcinoma, but this finding should be disregarded.

Oftentimes there is the possibility of grave error in diagnosis when tiny bronchoscopic specimens are studied microscopically. Sections revealing only squamous or columnar epithelium or granulation tissue containing a few small cells can be misleading. When these are obtained from the region of a polypoid tumor which has been seen bronchoscopically, additional specimens should be removed before venturing a diagnosis either of squamous cell tumor or of granuloma. In cases of adenoma, satisfactory specimens should be available from which the correct diagnosis can be made. According to our experience, errors in the diagnosis of bronchial adenoma are very rarely made if the microscopic features which have been outlined are given consideration and the precautions concerning specimens are borne in mind.

In accordance with the foregoing description, uniformity of the cells and the rarity or absence of mitotic figures proclaim the benign nature of the neoplasm in so far as microscopic features are concerned. There was a period in which pathologists confused adenoma with malignant growths, but this phase has passed and it is safe to say that at the present time most pathologists agree on the distinctive microscopic features of the neoplasm to which the name "adenoma" is generally attached. Now, however, there are those who regard "adenoma" to be a misnomer on the basis of microscopic features, said to be those of mixed tumors or of carcinoma.

Against this background we wish to present an analysis of a series numbering more than 64 cases, because the continued study and follow-up for many years permit conclusions drawn from long observation and experience. Before doing so, however, a survey of the literature on the subject is in order. A complete analysis made in collaboration with Dr. Oscar Friedman will be set forth in another publication; only some features germane to our present purpose will be mentioned here. Excluding cylindromas, at least 368 certified cases of bronchial adenoma were found in the literature. By "certified" we mean cases with specimens removed by bronchoscopy, by operation, or encountered at autopsy. Statements which lack such evidence are omitted for obvious reasons. Of the 368 cases, 100 consisted of operative removal with reported specimens, 23 were autopsies, and the remainder, bronchoscopic material. Significant features in relationship to the question of malignancy can be gleaned only from the operative and autopsied cases. They can be summarized as follows:

1. There were 43 lobectomies without a single instance of involved nodes. Pneumonectomy was performed in 60 cases, of which 13 had involved nodes.

Of the 23 autopsied cases lymph node involvement existed in 5. There were 3 instances of remote metastases: a nodule in the opposite lung, one in the liver, and a microscopic metastasis in the bone marrow without lymph node involvement. In any event, there is no reported case presenting the usual features of malignant extension.

2. It is impossible to ascertain the proportion of cases in which extension beyond the bronchial wall existed, and therefore in which complete eradication endoscopically might have been feasible. Extension beyond the bronchial wall is slight in most of the reported cases. There is no ulceration, necrosis, or diffuse invasion of adjacent tissue when so-called malignant transformation takes place.

3. Involvement of lymph nodes, which in the reported cases is limited, is usually by direct extension from the primary tumor, the involved nodes being immediately adjacent to the tumor.

4. "Malignant transformation" is characterized solely by immediately adjacent involved nodes or remote, usually minute, metastases which have been already mentioned as extremely rare occurrences. In either case there are repeated microscopically the features of the primary tumor, uniformity of cells and, with rare exceptions, absence of mitoses.

5. The mean period of the duration of symptoms in cases with lymph node involvement was from twelve to fifteen years, indicating that the metastases were either of long duration or occurred very late in the disease, in contrast with the usual course of malignant tumors.

6. Whereas the average age of onset of symptoms in bronchial adenoma was 28 years in 100 reported cases, the mean age of onset of patients with metastases was decidedly less (about 20 years). Thus, the literature portrays a most peculiar and benign form of malignancy, encountered in less than 10 per cent of the cases.

It can be stated at once that an analysis of our 64 cases yields results which are not significantly at variance from those we have culled from the literature. However, our long follow-up study offers a rounded picture of the life history of bronchial adenoma which cannot be obtained from the literature. Furthermore, case reports often are lacking also in the details of clinical features which are related so closely to the life history of bronchial adenoma, and some attempt will be made here to repair this ommission.

Turning briefly to a restudy of the sections of the 64 cases we may say that bronchial adenoma is established as a distinctive pathologic entity. True gland formation being absent in most instances, the term "adenoma" is inaccurate to this extent, as also in thyroid adenoma for example. All the characteristics of mixed tumors are not seen. Calcification and ossification as noted in adenomas elsewhere are unusual. Islands of cartilage or bone almost always represent remnants of cartilaginous rings which may be ossified. Cylindromas comprise a separate entity and should not be included with bronchial adenoma.

The microscopic features and macroscopically circumscribed limits of bronchial adenoma were maintained in the 5 instances of metastases in our series. Of these 5 cases the metastasis was confined in 2 cases to a solitary unusually large node immediately adjacent to the smaller primary tumor. The age of one of these patients was 14 years, of the other, 64 years. The roentgen evidence in the former points to the presence of the metastatic node essentially unchanged for a period of more than five years. Thus, as in the literature, the term "malignant transformation" applied to bronchial adenoma is one of common usage but is not justified by the evidence. Instead, each case of lymph node invasion can be properly referred to as a case of bronchial adenoma with regional lymph node involvement. Even in the presence of metastases the term bronchial adenoma should be retained, in our opinion.

A summary of the clinical course in our cases reflects the essentially benign nature of bronchial adenoma. Unless complicated by infection the course is not progressive as in malignant tumors. This is in keeping with slight growth over periods of many years. The course also remains essentially unaltered in the presence of so-called malignant transformation as signalized by involvement of adjacent lymph nodes.

A study of our case histories reveals a variety of presenting clinical pictures. There may be mentioned in passing cases in which the first symptoms and physical signs are those of recurrent pneumonia, bronchiectasis, pulmonary abscess, or stenosis of the middle lobe. However, we wish to emphasize here a syndrome which can be properly termed an "adenoma syndrome" because it was present in at least 32 of 62 completely documented cases. It consists of a history of recurrent clean hemoptysis (fresh blood not admixed with purulent secretion) and evidence of bronchostenosis (by symptoms, physical signs, and roentgenogram), occurring in a young individual. In an older individual the syndrome is distinctive of adenoma when of long duration. There is also an "adenoma syndrome" of a negative sort in which there is evidence of bronchial obstruction, with no sputum and no hemoptysis.

Turning now to the situation of the tumor, we can report on 58 cases in which our information is precise. Using terms which are generally employed, the bronchial adenoma was situated in a main bronchus in 12, upper lobe bronchus in 5, lower lobe bronchus in 26, middle lobe bronchus in 6, and in a branch bronchus in 9. The middle lobe lesion is worthy of separate consideration but for present purposes (that is, discussion of therapy) can be regarded as a branch bronchus. The degree of invasion of the bronchial wall can be stated with certainty only in removed or autopsied specimens of which we can report on 25. In 6 the tumor was purely endobronchial. In most of the remainder, the extension through the bronchus was limited. In 2 the extrabronchial portion was very much larger than the endobronchial. It is proper to point out that vertually all these cases were operative ones, and as such are to be contrasted with those in which bronchoscopic treatment was employed.

The cases in which treatment was bronchoscopy and which will be reported in detail by Kramer and Som are referred to here chiefly because of cures which were achieved. The following results are stated on the basis of long follow-up: Adenoma of main bronchus, 5 cures, 1 failure; of upper lobe bronchi, no cures, 2 failures; of lower lobe bronchi, 7 cures, 7 failures; of middle lobe bronchi, 2 cures, 4 failures; of branch bronchi, no cures, 3 failures. Cases are listed as cures only when repeated biopsies of the base at intervals of months to years after endoscopic removal of the tumor establish the absence of neoplastic tissue. It will be noted that the most favorable area for cure is *adenoma of a main bronchus*. The reason may be in part more ready accessibility but also a lesser tendency to bronchial penetration of main bronchus adenomas. This is high lighted by a study of the specimen in one case in our series in which pneumonectomy was performed but in which cure by bronchoscopic treatment could certainly have been achieved. It should be emphasized that failure of treatment to effect a cure in our series of cases is not synonymous with failure of treatment since not a few of the patients were cured symptomatically for long periods of time. Furthermore, one of the indications for radical operation as stated in the literature is infection distal to the neoplasm. Undoubtedly bronchiectasis resulting from tumerous bronchostenosis and infection is irreversible but this does not necessarily demand surgical eradication. In our series were 5 patients with suppurative bronchiectasis in whom there was not only complete endoscopic removal of the tumor but also disappearance of infection.

There is not sufficient time for a discussion of the indications for and contraindications to endoscopic treatment of bronchial adenoma. There can be no question, however, as to the inadvisability of persisting in the bronchoscopic treatment of adenomas in branch bronchi or of adenomas in any bronchi when there is evidence of extension beyond the wall. Thus, it is clear that *lobectomy is indicated for branch bronchus tumors and for most tumors in the upper and middle lobes.*

There are two main indications for pneumonectomy for main bronchus tumors: (1) Extension beyond the wall of the bronchus and (2) regional lymph node involvement. According to the evidence which has been presented, the indication is not to be based on the assumption that bronchial adenoma is a precancerous or cancerous lesion. For example, we performed a pneumonectomy on a woman 64 years old for a circumscribed tumor erroneously thought to be a primary cancer of the lung. This proved to be a bronchial adenoma with an adjacent involved lymph node which resembled roentgenologically a circumscribed cancer of the lung. The patient, who was not a good surgical risk, had been virtually symptom-free and had not only carried the lesion for many years, but also would have borne it well indeterminately in all probability. Had we known the nature of the lesion we would have withheld operation despite the involved regional node. To cite instances in which pneumonectomy has not been performed and yet the course has been satisfactory, there are a few patients in whom symptoms subsided entirely or in large part after partial bronchoscopic removal of the tumor, and in whom death occurred much later from unrelated causes. There are two cases in which drainage of the empyema was the sole procedure and the subsequent course has been satisfactory. Perhaps the advocates of uniform radical operation might, or would, concede conservative treatment in the old or poor-risk patient under certain circumstances. What about the young and good-risk patients who make up the preponderance of the cases? With the present-day development of thoracic surgery virtually no mortality and but little morbidity need be anticipated in such patients whether subjected to lobectomy or pneumonectomy. The argument concerning the malignancy of bronchial adenoma thus becomes, according to this view, merely one of didactic interest. However, it is because most of the patients suffering from bronchial adenoma have many years to live that they should not be deprived unnecessarily of large areas of pulmonary tissue. This discussion may be closed aptly by reference to a patient who has done well after a pneumonectomy for adenoma performed six years ago. The report from another source on the bronchoscopic specimen was "malignant neoplasm." The operative specimen revealed a main bronchus adenoma ideal for endoscopic removal. There is surely no justification for pointing with pride to the result of surgery in this case. To conclude, there is full justification for the conservative treatment of selected cases of adenomas in the main and lesser bronchi, just as the evidence is clear in favor of lobectomy or pneumonectomy in other cases of bronchial adenoma.

SUMMARY

Bronchial adenoma is a clinicopathologic entity. Clinically a syndrome termed the "adenoma syndrome" occurs in the preponderance of cases. The microscopic characteristics are those of a benign neoplasm, with an orderly arrangement of distinctive cells and a virtual absence of mitotic figures. Metastasis is not common and when present it consists usually of limited involvement of an adjacent lymph node, in which the pattern of the parent tumor is repeated. Remote metastases are extremely rare and consist usually of minute deposits which repeat the pattern of the primary tumor. Bronchial adenoma occurs in the larger bronchi in the great majority of cases, rarely in bronchi which are too small to be accessible to the bronchoscope. The tumor may be situated superficially within the bronchus or extend through the wall to a varying degree. Complete eradication of a superficially situated tumor can be achieved by endoscopic treatment particularly when the tumor is situated in a main bronchus. Not only cure but also subsidence of infection and retention of the lung can be achieved thereby. In the case of extension into or beyond the bronchial wall, local excision by bronchotomy as advocated by Eloesser can be considered. The contraindications to bronchoscopic treatment are outlined. The indications for lobectomy or pneumonectomy are stated.

The treatment of bronchial adenoma should be based on the concept of a benign neoplasm with a long life history and not on the concept of a cancerous or precancerous lesion.

DISCUSSION ON "THE MALIGNANT NATURE OF BRONCHIAL ADENOMA" BY DR. ALFRED GOLDMAN,* AND "ADENOMA OF THE BRONCHUS" BY DR. COLEMAN B. RABIN AND DR. HAROLD NEUHOF

DR. EVARTS GRAHAM, St. Louis.—These two papers which we have just heard have been of enormous interest to me, but I must say that they leave me somewhat confused. Many of you will remember that two years ago we heard an extensive discussion of this subject. There were in all 15 or 20 cases reported by various discussors as well as by myself, who gave the paper on the question of so-called adenoma of the bronchus, in which there was undoubted evidence that distant metastases had taken place in these tumors. Now I am very happy to find that Dr. Goldman, I think I am correct in saying, has changed his attitude. Perhaps I am misquoting him, but I believe I am correct in stating that he thought only a few years ago that these tumors were never malignant. I do not know why it is so hard for this idea to die in the minds of everybody, that these tumors should never be considered malignant. Dr. Neuhof has referred to the unwillingness of pathologists to accept the idea that these tumors are potentially malignant, a point which many of you know Dr. Womack and I have been trying to develop successfully for a period of about eleven years now.

Now I do not agree with Dr. Neuhof, if I understood him correctly, that pathologists in general are reluctant to admit the potentiality of malignancy in these cases. I would say, on the contrary, that my own inquiries, not only in the United States but also in England last fall, convinced me that more and more pathologists have come around to the point of view that these tumors are potentially malignant. Perhaps Dr. Neuhof has that idea because he makes the statement, which to me is a very strange one, that he would exclude the cylindromas and the mixed tumors which are malignant and talk only about the adenomas. In other words, he says, "I will dismiss from my talk those which are malignant, and confine my remarks only to those which are not malignant." And yet he mentions that even among the group which he designates as having a benign form of malignancy—whatever that is, I do not know—there is involvement of the lymph nodes, involvement in two instances of the liver, and bronchial wall invasion.

My idea, and my definition of malignancy in a tumor, is evidently totally different from his. It is impossible in a few minutes' time to develop this idea again; I am almost ashamed to stand up here again and redevelop these points which we have emphasized in various articles in the literature over a period of about eleven years. We have never indicated that we thought all these tumors were malignant; we have never indicated that we thought these tumors were malignant at all times. When one considers the question of potential malignancy, one assumes, of course, that something happens to a tumor which is present, the nature of which happening we do not know, but the tumor becomes malignant; something happens to the tumor, sets off a trigger, and it becomes malignant. Now it is entirely possible, of course, that under such circumstances, and there are many other examples in other parts of the body which I will not take time to mention, it is entirely possible that if one sees these tumors in the premalignant stage, of course he will consider them as benign tumors and of course at that time they will be benign tumors. I maintain, however, that the evidence is very strong now that many of these tumors become malignant, and I will state also that I have had three cases of extensive metastases in the liver, of the sort of tumor which Rabin and Neuhof designate as benign adenoma.

I think it is a curious fact, and a very interesting and important one, that except for an occasional and very exceptional report in the literature, nobody knew anything about bronchial adenomas until within the last eighteen or twenty years; in other words, it has been coincidental with development of the bronchoscope. Can one imagine that pathologists, the most famous pathologists in the world in those days, would have failed to see bronchial adenomas; in doing autopsies could one suppose they would have failed to see them? Does it not seem probable that they would have attracted some attention, because they are interesting tumors, they are curious tumors? Would it perhaps be fair to make a suggestion such as Dr. Womack and I made in our article in 1937, and as Dr. Goldman has also said today, is it not a fair assumption that many of these tumors when they become wildly malignant or definitely malignant make it impossible for the pathologist to recognize that they have originated in an adenoma in the bronchus, because it is impossible to tell after they have spread all over and have involved all the organs. Now, if there were such an occurrence, what sort of tumor would we expect to find? Remember that this adenoma that Dr. Neuhof is talking about is composed of little round cells, scanty cytoplasm, almost entirely nucleus. Dr. McDonald tells us, and shows us a picture, and says that the British call the most malignant type of bronchiogenic carcinoma the oat cell carcinoma. The cell which is seen in these so-called oat cell carcinomas looks exactly like these cells which you see in the bronchial adenomas that Dr. Neuhof is describing. I will pose the question again, then. Is it possible that sometimes these tumors become so malignant that they are recognized only as so-called oat cell carcinomas but which had their origin perhaps in a so-called bronchial adenoma?

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*See page 137 for article by Goldman.

One more point which has been mentioned here this afternoon is that these adenomas are characterized by the fact that there is no ulceration in the mucosa overlying. That is true, but even without ulceration of the mucosa overlying I have seen two patients with metastases of the liver from which presumably they died. I have seen other cases with extensive lymph gland involvement. Finally, I would like to make one other statement which is not too conclusive. We have been interested in the very interesting technique which Dr. Harry Green of the Pathology Department at Yale has developed—I am sure many of you are familiar with it—of injecting pieces of tumor into the anterior chamber of the eye of guinea pigs. His contention is that no tissue will grow by such technique except two kinds, malignant tumors and embryonic tissue, and by embryonic tissue he means tissue taken from an embryo. We have recently transplanted so-called adenomatous tissue of the kind Dr. Neuhof is talking about, not the kind he dismisses as being malignant but the kind he says is benign-malignant, into guinea pigs' eyes. Unfortunately, there has not been time for me to find out just what has happened to these guinea pigs, but I had a telegram Saturday afternoon from Dr. Kemler, who has been doing this work, and he said there is a growth in the eyes but he had not yet had time to examine it. I am making that statement for what it is worth. It is not conclusive but we shall report on those findings later after we have had an opportunity to study them.

DR. OSLER ABBOTT, Atlanta.—There is no more intriguing pathology in the lung than so-called adenoma. I also feel that I am not certain what to do about it. I was brought up and trained on the theory that it should be removed by total pneumonectomy. Reports have come out that these tumors may be arrested with lobectomy alone. Our policy in Atlanta had been to do lobectomy for adenoma and if the immediately resected section shows no node involvement, the operation is discontinued at that point. We felt happy with this type of procedure until we encountered a patient a little over a year ago in whom there was an adenoma and in whom considerable lymph gland involvement was noted throughout the mediastinum. A total pneumonectomy was done; there was absolutely no involvement of the glands removed, but a careful examination of the tumor microscopically revealed several microscopic fields in which there was unquestionable transformation of this tumor from its basic cellular structure into a grade 3 squamous cell carcinoma. This experience has been repeated on three occasions since then, and in every case the adenoma has transformed itself into a squamous cell carcinoma with major areas of intact so-called ''benign adenoma tissue'' about it. Two other patients have been encountered in whom the tumor did not transform itself and there was very extensive invasion of the posterior chest wall on the left side. One patient had extremely extensive invasion of the major mediastinal vessels. I feel that the lesion is only ''benign'' in its cell structure as it stands, but it is definitely premalignant clinically and can transform into a squamous carcinoma. Whatever type an oat cell carcinoma may be, it could very well have its origin in an adenoma.

DR. CHEVALIER L. JACKSON, Philadelphia.—I remember the occasion Dr. Graham referred to; at that time I reported twenty cases encountered at Temple University Clinic. Since that time we have seen twelve more such patients. Of the original twenty, three had been treated surgically, with lobectomy in two instances and pneumonectomy in one, and seventeen bronchoscopically. At the present time those patients are status quo except for one of those treated bronchoscopically, who has just recently had a very successful lobectomy, with removal of the middle and lower lobes, not because there was progression of the tumor but because she still had recurring attacks of cough with some production due to the bronchiectasis in the lower lobe. Of the twelve new cases, seven patients were treated surgically and five bronchoscopically.

I believe that the crux of the confusion lies in the pathologic and histopathologic diagnosis. I think, as Dr. Neuhof and Dr. Rabin have said, we should eliminate the mixed tumors and cylindromas, and consider these as separate groups. It is extremely interesting to hear Dr. Rabin's view on this, since he is one of the pioneers in the study of these cases. I do not believe true adenomas have any inherent tendency to become malignant, but I do not say they *never* may become malignant. However, I think treatment depends by no means entirely on the pathology; that is, on malignancy or benignancy. Bronchoscopy is always indicated first, for study and biopsy, and for clearing up the lung. Bronchoscopic removal may be curative when the tumor is attached by a narrow pedicle; bronchoscopy will be helpful always when there is need for improved drainage. The indications for pneumonectomy or partial resection are, in my opinion, chiefly in cases where it is impossible to remove the tumor bronchoscopically, and in cases where there has been irreversible damage to the distal portion of the lung as a result of prolonged bronchial obstruction.

DR. ALEXANDER E. W. ADA, New York.—I wish to present two cases which illustrate the problem under discussion. The first is that of a 52-year-old white woman, admitted to St. Luke's Hospital, New York, in May, 1947. She had experienced recurrent hemoptyses for the past twelve years. In December, 1943, bronchoscopy was performed at another hospital and a biopsy was taken from a tumor in the left main bronchus. The microscopic sections were thought to represent adenoma, although certain areas showed definite irregularity in the arrangement of the cells. One year later two successive bronchoscopies were performed in an attempt to remove the tumor. In February, 1947, another bronchoscopic biopsy was reported as adenocarcinoma. Laminographic studies showed a tumor in the lumen of the left lower lobe bronchus, with peribronchial infiltration. Findings on routine x-ray films of the chest were essentially negative. On June 2, 1947, a total pneumonectomy was performed, and recovery was uncomplicated. On gross pathologic examination, a pedunculated rounded tumor, 2.5 by 2 cm., was found just within the opening of the left lower lobe bronchus, projecting into the main branches. The tumor had a depth of 2.5 cm. and extended outward into the surrounding lung. Two centimeters distal to the tumor there was a second one, 2.5 by 1.5 cm. in size, which was similar to the first. The lower lobe showed enlarged thick-walled bronchi and bronchioles with the appearance of bronchiectases and areas of fibrosis.

Sections through the pedunculated portion of the growth showed that toward the surface the tumor was composed of long chains and anastomosing strands of rather small epithelial cells, suggesting an origin from the basal layer of the mucosa. These had a glandular pattern, but the cells were about the same size and shape, stained very deeply and, for these reasons, did not suggest a very highly malignant growth. In certain areas, however, they had invaded the cartilage of the bronchus and here there was also considerable bone. The latter was surrounded by tumor and the cartilage was detached from the perichondrium. In these areas the lymphatics were invaded, but not the nodes. Pathologic diagnosis was adenocarcinoma of bronchus, nodes not involved.

The clinical course in this patient and the early bronchoscopic and pathologic findings tended to confirm the diagnosis of adenoma. However, over a period of years the tumor seems to have acquired some of the characteristics of malignancy. This case also illustrates the possibility that more than one tumor may be present and escape recognition.

The second patient was a 35-year-old white woman, who was admitted to St. Luke's Hospital in July, 1947. Five years before, she had been hospitalized for a virus pneumonia. Soon after, she developed occasional pain in the left chest, accompanied by cough and hemoptysis. These symptoms persisted one or two weeks at a time and recurred at about monthly intervals, usually at the time of menstruation. Four years before, bronchoscopy had been done, with the diagnosis of adenoma of the lung, although the histology was more typical of lymphoblastoma. Bronchoscopic biopsy one year later was diagnosed carcinoma, and a repeat bronchoscopic biopsy in April, 1947, was diagnosed adenoma.

On admission, the x-ray films of the chest showed no pathologic lesion or abnormality. On bronchoscopy a large papillomatous red mass was visualized, filling the opening of the left upper lobe bronchus. Microscopic diagnosis of a biopsy was adenocarcinoma. On July 15, 1947, a successful left total pneumonectomy was performed.

Pathologic examination showed the tumor to arise from the posterior wall of the upper lobe bronchus. It projected into the lumen and extended toward the hilus and downward into the lingular division. Microscopic examination of the tumor showed it fungating into the lumen, where it was composed of many solid sheets of cells with a glandular arrangement. The tumor cells infiltrated the wall deeply and extended to the cartilage which was partially destroyed. The cells were also outside the cartilage in the peribronchial tissue; however, the nodes were not involved. Pathologic diagnosis was adenocarcinoma of the bronchus; nodes not involved.

These two cases tend to confirm the experience of others, that adenoma of the bronchus may undergo malignant changes, and that certain tumors presenting similar clinical features and bronchoscopic appearance may be be malignant tumors from the onset. It is evident that a correct diagnosis cannot always be obtained from one or more bronchoscopic biopsies. Under the circumstances it would seem that the necessity of pulmonary resection should be of prime consideration and, if performed early in the disease, more conservative excisions or procedures would suffice to effect a cure.

DR. JOSEPH GORDON, Ray Brook, N. Y.—I should like to give a follow-up report on ten cases that have had a period of five years' observation. At the time of the original report by Dr. Chamberlain and myself, seven patients were reported as recovered, two died, and one was inoperable. We now have a report on six cases. Five are considered well, although one has a sinus tract infection. The sixth case is of interest to Dr. Graham. The left lobe of the liver was removed in Albany by Dr. Dickinson, and the tumor cell is identical with that of the bronchial adenoma. This patient has returned to work following lobectomy of the liver.

DR. D. H. WATERMAN, Knoxville, Tenn.—Personally, I agree with Dr. Graham and Dr. Abbott in saying that these are malignant or premalignant tumors. I would like to call attention to the bleeding that occurs on biopsy. As you know, hemoptysis is a very common symptom in the history. We have had four cases in our series in which terrific bleeding occurred when bronchoscopic biopsy was taken, one of these terminating fatally.

I believe Dr. Gordon mentioned that he had had two cases in his series where death occurred at bonchoscopy. We have been rather reluctant to treat or even biopsy these tumors through the bronchoscope when we felt resection should be resorted to anyway.

DR. W. E. ADAMS, Chicago.—A few years ago, Dr. Bloch, Dr. Steiner, and I reported on a group of these patients, and in that group there were three autopsies. One patient died from asphyxia due to obstruction of the trachea by tumor; another from pneumonia; and the third following operation. We called attention to the fact that mediastinal node metastases, and in two of the three, distant metastases to the vertebrae or liver were found. Since that time we have had experience with another patient: a 34-year-old woman who, in 1934, had a circumscribed upper lobe lesion; the sputum was negative. She was given x-ray therapy with complete disappearance of the opacity. She had no symptoms until 1942, nine years later, when hemoptyses began and the lesion appeared as in the original roentgenogram. Resection was recommended and was delayed for some months. We found no evidence of involvement of the regional lymph nodes. Eighteen months later she had a pelvic operation, and the liver was found completely studded with nodules. One of these was removed, and showed the same cellular formation as that of the original lesion. She has been completely asymptomatic since operation and shows no signs of metastases. We know, since this has been demonstrated microscopically, that she does have metastases to the liver and we do not know where else.

Experience has led us to believe that these tumors must be considered malignant; slow-growing carcinoma is a good term. From the microscopic appearance one cannot predict which of these lesions will metastasize. Thus, all should be considered potentially malignant. One cannot classify the tumor as to the rate of growth. We know that a squamous cell carcinoma may be present for years without producing symptoms.

Addendum.—This patient recently developed signs and symptoms of cerebral metastases and died shortly thereafter.

DR. EDGAR W. DAVIS, Washington.—Last night and again this morning I talked to several members of this Society about adenomas and to my amazement Dr. Graham a few moments ago used the same expression I heard last night, "We are confused." To listen to the various discussions on the management of adenomas is often more confusing. It would seem that it is virtually impossible to obtain uniform opinions from various pathologists as to the malignancy or benignancy of these lesions. It is nice to have a correct preoperative diagnosis on a patient but I do not agree that this is a clinicopathologic entity because I find from bronchoscopic biopsy and even from the surgically removed specimen that pathologists of repute differ widely in defining the nature of the lesion. It is for this reason that I doubt that the histologic report of a biopsy should necessarily dictate our mode of therapy. One pathologist may classify a given section as a grade 1 or grade 2 malignancy, whereas another pathologist may classify it as a benign lesion.

It has been our policy in the management of these so-called adenomas to take a bronchoscopic biopsy if possible. If all the tumor can be removed bronchoscopically and if all the sections by different pathologists are called benign, nothing further is done. If, however, there is any question as to whether it is a benign lesion or if it is not entirely accessible to the bronchoscope, a lobectomy or segmental resection is done. If the pathologist then reports a benign lesion it is unnecessary to sacrifice any additional lung tissue. If it is reported as questionably malignant, we do not believe anything short of a lobectomy should be done.

DR. CLARENCE CRAFOORD, Stockholm.—We have one case in which operation was done in 1936 with total pneumonectomy, which in some respects illustrates the question of malignancy of bronchial adenomas. At the time of operation the diagnosis was bronchial carcinoma. There was invasive growth in the mediastinum and metastases were found in mediastinal lymph nodes. A study later on of the specimen, however, showed that this tumor without doubt belonged to the group of mixed salivary gland tumors to which group we consider the so-called bronchial adenoma to belong. That patient was well until 1946, when he came back with recurrence in the bronchial stump and with clinical evidence of tumor growth in the mediastinum. He died about one year later. In this case there were undoubtedly clinical signs of the bronchial tumor so far back as seven years before admission. This case and many more in our experience have shown us that if tumors of this type are to be considered as potentially malignant, they cannot be clinically regarded malignant in the same sense as real carcinomas. If within a reasonable time they can be locally radically excised, the risk of a recurrence must be considered as very small. Because of that we have now come to the conclusion that it is advisable to treat these tumors more conservatively than carcinomas. As it is impossible to diagnose if there is in addition to the intrabronchial bronchoscopically visible growth also an extrabronchial extension in the great majority of cases, we are now of the opinion that endobronchial removal of the tumor is not to be con-

DR. GOLDMAN.—There is not time to answer all the problems raised. I have changed my mind from what I thought at the time I read the paper before the Society in 1938. We had never observed up to that time any lymph node metastases, and we followed some patients for twenty years. The first patient reported in that paper was operated upon about 1915, when empyema and abscess were drained. The tumor was as large as a grapefruit when the patient died. There was no lymphoid involvement.

I have modified my opinion to this extent. There are varieties of adenoma. One variety which was shown is cylindroma or mixed tumor. Of this variety shown in the first case, I have seen two cases. The other patient also died after bronchoscopic removal of the tumor. Early surgery with removal was not done. I believe we should differentiate the adenoma group from cancer, if for no other reason than that when we operate and remove the tumor the patient's chances are so much better, and I believe we should always separate them from carcinoma in reporting statistics.

I am somewhat pleased to find the evidence as reported by Dr. Abbott and Dr. Gordon, that these tumors may metastasize and go for many years without producing death. It seems to me they metastasize whether they are old or young. It seems local lymph node metastasis does not always occur, but is perhaps more often found in older tumors. Regarding what Dr. Crafoord said, I reported a case in 1947 which had primary bronchoscopic removal, and after three years there was local bronchial recurrence. When a lower left lobe resection was done a tumor nodule could be seen inside and outside the bronchus. This patient has had symptoms for twenty-five years and there is no sign of metastases. If in a given case all the tumor can be removed by bronchotomy, local surgical resection, there are patients in whom that can be done to conserve the lung. Regarding Dr. Eggers' cases I do not agree completely that local removal is always successful. I have seen deaths from attempt at bronchoscopic removal. I am sure every bronchoscopist is alarmed by the large amount of bleeding which may occur. Particularly where there is suppuration, opening the bronchus will not cure that patient any more than a chronic abscess, and resection should still be done for the original disease.

There is much more to be said about his subject. The ideas of the origin, and the ideas we have as to the growth of these tumors may be modified. Dr. Nathan Friedman has an idea about mixed tumors. He considers that these tumors, arising from the original cell, may form two or more different cells—and they do not have to go through a complete life cycle to complete malignancy—they may die out; thus some adenomas may develop to a certain point and go no further, and perhaps others go to complete malignancy.

DR. RABIN.—In this prolonged discussion it has been emphasized that certain members have been left with a feeling of confusion. I may say this: where confusion begins, this is the beginning of clarification. Years ago this tumor was reported simply as carcinoma and therefore did not constitute a special problem. Dr. Harry Wessler, to whom belongs the credit for recognition of the tumor, was confused when the pathologist reported several such tumors of long standing in young women as malignant. Dr. Mandelbaum admitted the growths were peculiar and different from carcinoma, and he said: "If it is shown to me that they run a benign course, we must consider them benign, even though to me as a pathologist they appear malignant."

We have passed a certain phase in the confusion regarding these growths, that is, confusion with ordinary forms of carcinoma. We have not passed the point of confusion of the adenoma with other unusual tumors. A few slides will illustrate this: (Slides.) The type shown on the screen falls into the group called the carcinoid type of adenoma which, together with the acinar type, make up the category of bronchial adenoma. I would exclude the cylindroma, which looks like certain portions of salivary gland tumors, mixed tumors containing bone and cartilage and sometimes other elements, and the entire group of mixed tumors, including osteochondroma. In addition, tumors resembling certain basal cell carcinomas of the skin showing cystic adenomatous changes are more properly relegated to carcinoma or cylindroma and should also be excluded.

Before formulating a clinical classification of the growth one must start with a pathologic classification. The pathologist must classify what he sees microscopically, and then follow the pathologic course of the growth before he can help the clinician in planning treatment.

In this respect I wish to show the following slides. This table shows five cases with tumors in the main bronchus, and no response to endoscopic therapy. They show a history of from seven to thirty-seven years, and how much longer the tumors were present we do not know. There we have failure of endoscopic removal in patients who have a long history averaging thirty-three years of symptoms. Here we have a group of fifteen patients who appear to be well after bronchoscopic treatment and who have been followed for a considerable time, without recurrence. One has been followed for fourteen years, and five have been followed *for more than ten years without recurrence being found. It must be concluded that at least* some of these patients are cured by simple endoscopic removal.

We are dealing with a growth different from carcinoma. We know the history is longer; we know the sex incidence is different from carcinoma. It comprises a distinct pathologic entity. Whether this tumor is amenable to a minor form of treatment or whether it requires resection of a large amount of tissue is not basic. We must separate from the adenoma other tumors that have a definite pathologic picture relating to other growths. When we do that we find the incidence of what has been called malignant change diminishes.

I do not think we have to define malignancy. We have to know what the growth does. Here is a tumor that grows for a long time (we have one half dozen patients who have had the tumor for thirty years)—a tumor which remains separated from the remainder of the bronchial wall in most cases, but in some cases does grow through the wall and even into the lung, occasionally involving the adjacent lymph nodes, and sometimes causes distant metastases, the tumor tissue still maintaining a benign appearance. These are not the characteristics of carcinoma in general and calling it carcinoma makes for confusion. We do not know what term is best to attach to this growth. The word adenoma is not a good one but should be retained until a better one is found.

There is little basis for considering that many carcinomas have their origin in bronchial adenomas. Dr. Head has pointed out that the duration of life in bronchial carcinoma is uniformly short. The only type of carcinoma that has a similarity to bronchial adenoma is the small cell carcinoma. These have the shortest history and this together with the absence of a polypoid appearance to these growths excludes the possibility of their origin in a bronchial adenoma. The paucity of reports of autopsied cases of adenomas must have some other explanation than that the adenomas have changed to carcinomas by the time the patients die.

THE CLINICAL USE OF A PROSTHESIS TO PREVENT OVERDISTENTION OF THE REMAINING LUNG FOLLOWING PNEUMONECTOMY

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WHEN the chest is closed without drainage following a pneumonectomy, the pleural cavity gradually becomes filled with blood and serum. In time, this fluid may be absorbed or it clots and contracts and, as a result, the mediastinum is drawn over to the affected side. This may produce considerable overdistention of the remaining lung (Figs. 1 and 2). This phenomenon may be prevented by a thoracoplasty done electively, or to obliterate the empyema cavity in case of infection (Fig. 3).

It has now been amply demonstrated that most patients do fairly well following a pneumonectomy without a thoracoplasty in spite of emphysema of the remaining lung. Many thoracic surgeons have had the impression that patients subjected to a thoracoplasty have had a better clinical result than those who were allowed to develop overdistention of the remaining lung. Cournand and his associates[1, 2] have presented data which tend to confirm this impression. They found both in children and in adults that the exercise tolerance was better in those patients in whom overdistention of the remaining lung was prevented by thoracoplasty.

Even though the thoracic surgeon agrees that overdistention of the remaining lung following pneumonectomy is undesirable, he may hesitate to subject his patient to an additional procedure as major as a thoracoplasty. If a simpler method of preventing mediastinal shift were available, it might be more widely used.

In a preliminary report,[3] we pointed out that overdistention of the remaining lung following pneumonectomy in dogs could be prevented by filling the pleural cavity with hollow plastic balls made of methyl methacrylate (Lucite).* In the dogs sacrificed after four months, there seemed to be so little foreign body reaction to the Lucite balls that a clinical trial appeared to be warranted. Our present report concerns observations made in dogs sacrificed one year after placing Lucite balls in the pleural cavity following pneumonectomy, as well as clinical experience with the use of this prosthesis in eight patients following pneumonectomy for carcinoma.

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Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

*The Lucite balls used in these experiments were obtained from the Nichol Product Company, Moorestown, N. J.

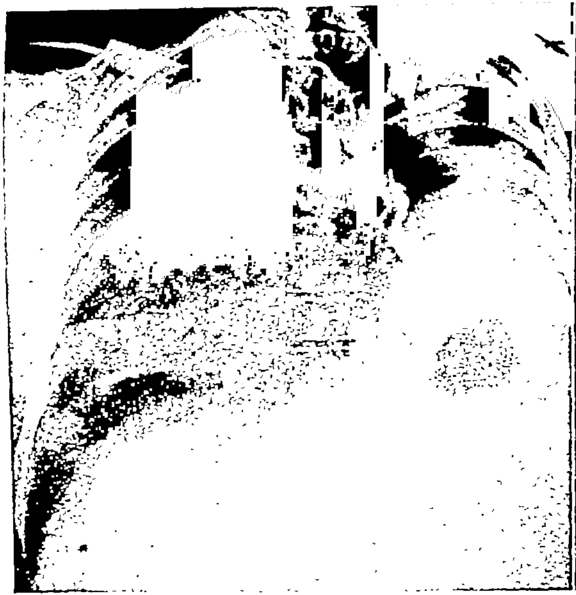


Fig. 1.

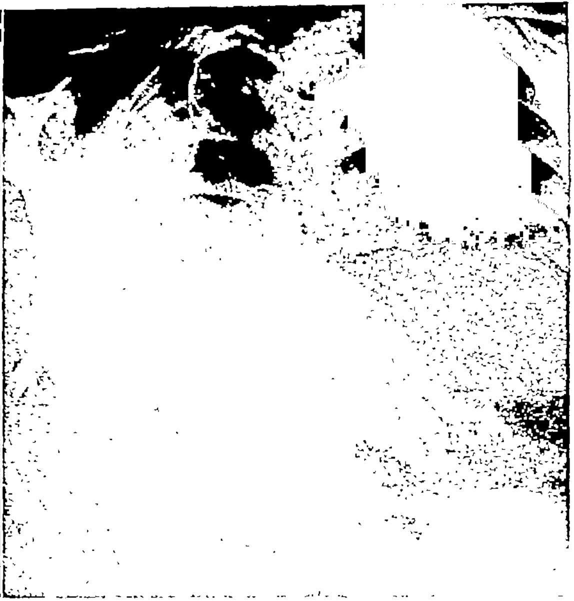


Fig. 2.

Fig. 1.—Severe overdistention of the right lung following left pneumonectomy for bronchial adenoma in a 50-year-old man. Barium in the esophagus shows it to be pulled over to the left. The right lung approaches the left side of the chest wall. (From Johnson and others: Surgery, August, 1947.[3])

Fig. 2.—Severe overdistention of the left lung following right pneumonectomy for carcinoma in a 58-year-old man. This man has had a five-year cure and complains only of some dyspnea on exertion. (From Johnson and others: Surgery, August, 1947.[3])

ANIMAL EXPERIMENTATION

As mentioned in our previous report, when no prosthesis was placed in the pleural cavity, the remaining lung became overdistended and partly filled the pleural cavity on the opposite side (Fig. 4). When Lucite balls were placed in the pleural cavity after removal of the lung, the mediastinum was maintained in the midline and overdistention of the remaining lung did not occur (Fig. 5, *A* and *B*). Since the previous report, four dogs were sacrificed one year following the insertion of the prosthesis. Four dogs remaining are living and apparently well approximately eighteen months after operation.

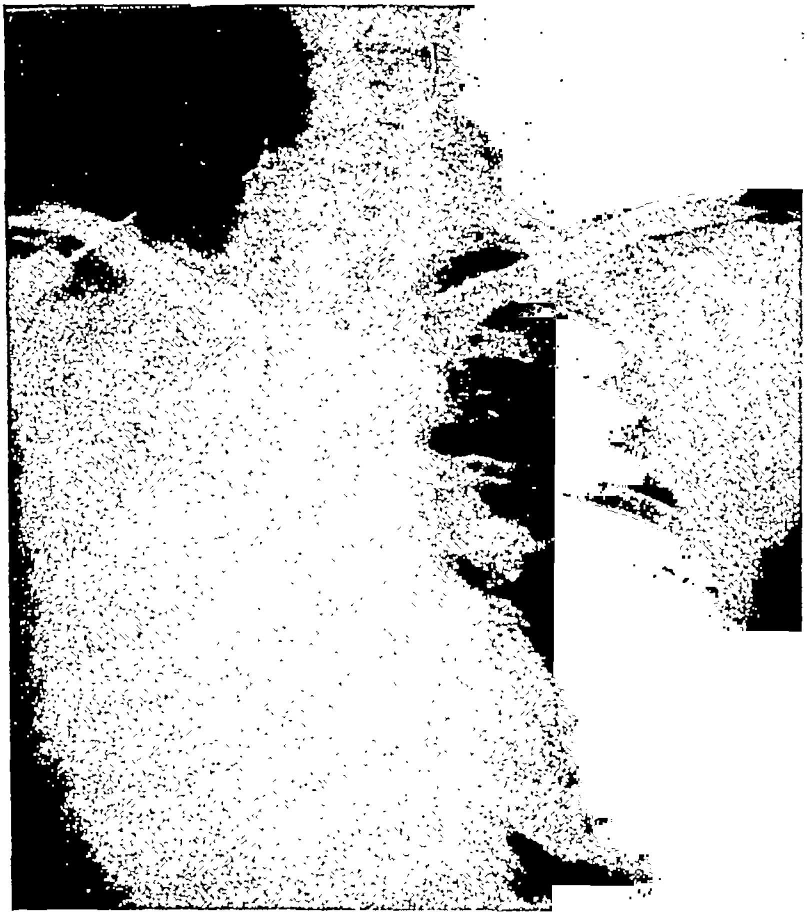


Fig. 3.—One year following right pneumonectomy and thoracoplasty for carcinoma of the lung in a 54-year-old man. The mediastinum is maintained near the midline and severe overdistention of the remaining lung is avoided. (From Johnson and others: Surgery, August, 1947.[3])

In all of the dogs the Lucite balls could be heard with a stethoscope to rattle with each heart beat. At autopsy in one dog each ball was found to be almost completely encapsulated by fibrous tissue with no fluid between the balls (Fig. 6). As seen in Fig. 7, the balls were still in contact at some points. Microscopic examination showed the tissue covering the balls to be acellular fibrous tissue with very little foreign body reaction (Fig. 8).

In the other three dogs, the Lucite balls were encapsulated as a group (Fig. 9). It appeared that each ball had its own niche as evidenced by the

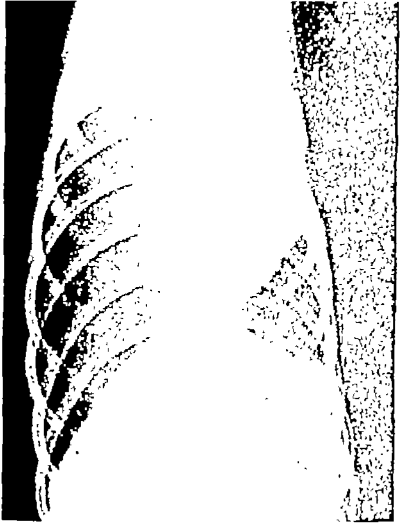
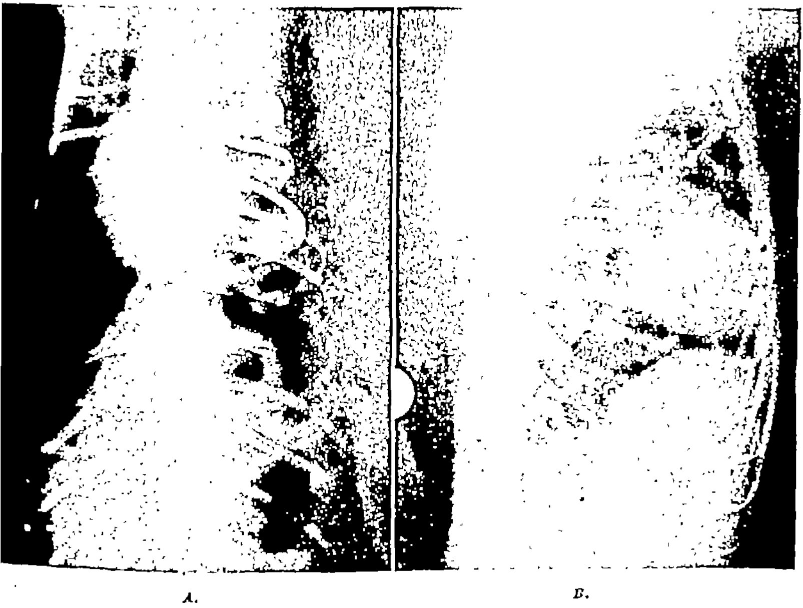


Fig. 4.—A dog two months following left pneumonectomy without the use of a prosthesis. The mediastinum is over against the left side of the chest wall and the overdistended right lung fills the lower part of the left side of the chest cavity. (From Johnson and others: Surgery, August, 1947.[8])



A.

B.

Fig. 5. *A* and *B*.—Anteroposterior and lateral views of a dog after left pneumonectomy with twenty-four Lucite balls in the pleural cavity as a prosthesis. (From Johnson and others: Surgery, August, 1947.[8])

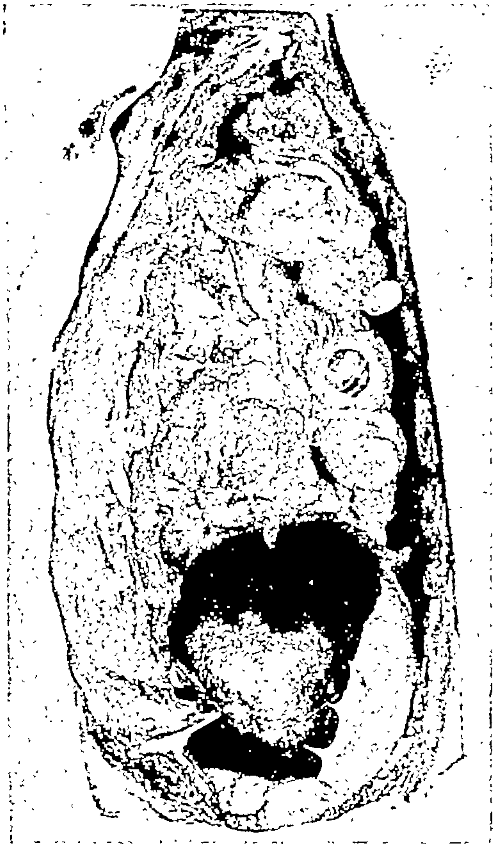


Fig. 6.

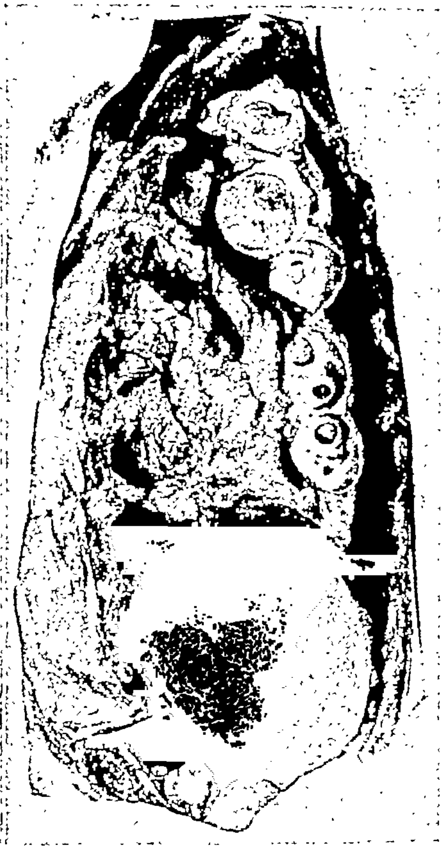


Fig. 7.

Fig. 6.—Dog sacrificed one year after pneumonectomy and insertion of Lucite ball prosthesis. In this dog the balls were almost encapsulated individually with fibrous tissue. There was no free fluid present.

Fig. 7.—Same as Fig. 6, showing that there was still contact between the balls at some points.

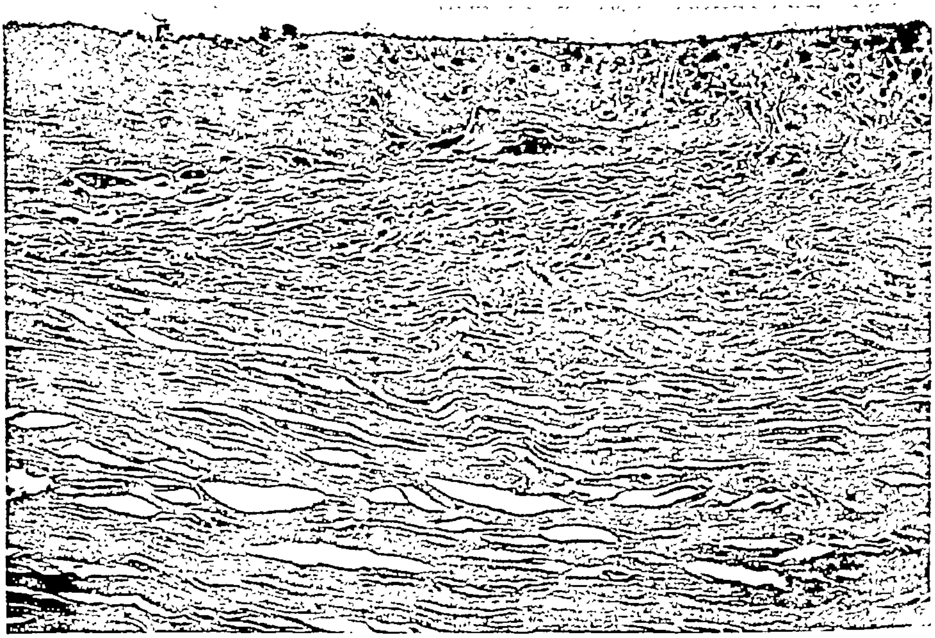


Fig. 8.—Photomicrograph of avascular fibrous tissue encapsulating Lucite balls in dog shown in Figs. 6 and 7.

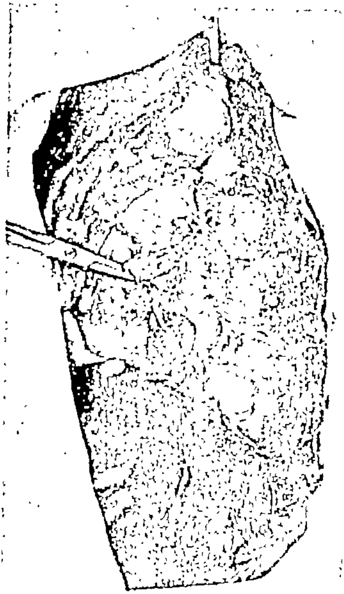


Fig. 9.—Dog sacrificed one year after pneumonectomy and insertion of Lucite ball prosthesis. In this dog the balls were encapsulated as a group. The space between the balls was occupied by clear fluid.

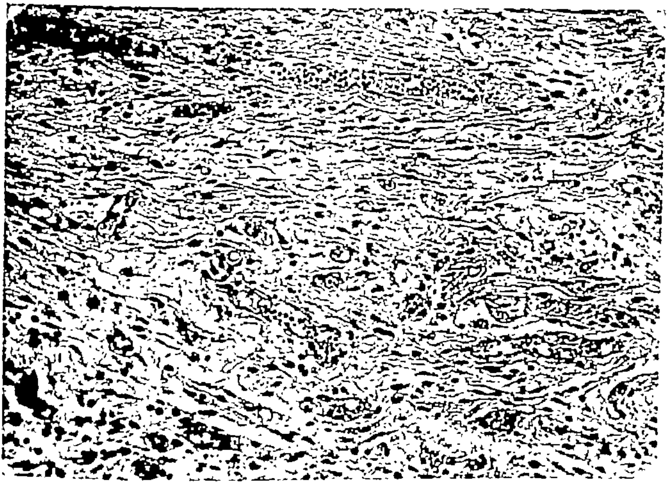


Fig. 10.—Photomicrograph of tissue removed from the pleura between the points in contact with the balls in dog shown in Fig. 9. This tissue is very vascular with cellular infiltration.

impressions on the surrounding pleura. The space between the balls was filled with clear fluid. Microscopic examination of the smooth pleura where a ball was in contact with it was similar to that in Fig. 8. On the other hand, the pleural surface between the balls had the appearance of granulation tissue (Fig. 10). The capsule surrounding the entire group of balls was thick and avascular.

A Lucite ball prosthesis seemed to be the most satisfactory of the prostheses considered for the following reasons: (1) conformity to a pleural cavity of any size or shape by varying the number of balls; (2) lack of evidence of increased infection in the pleural cavity; (3) minimal foreign body reaction; (4) ease of removal through a small incision in the event of infection; and (5) lightness of weight.

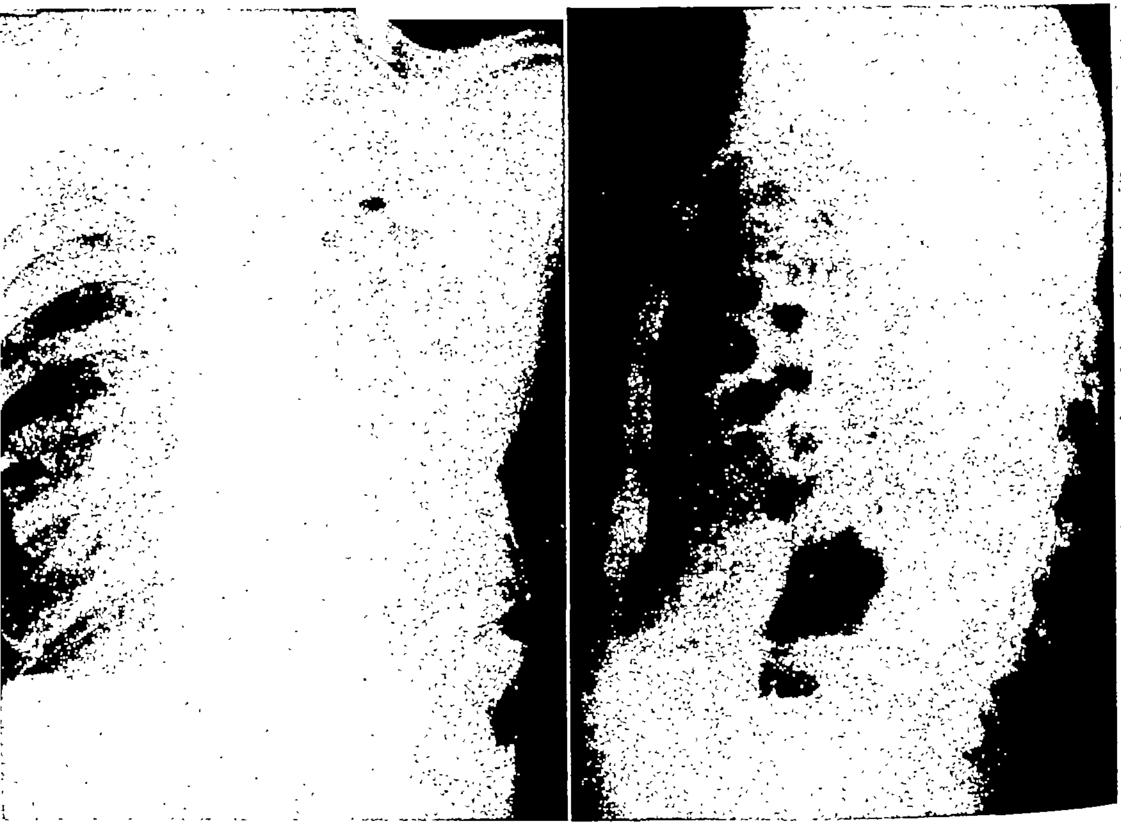
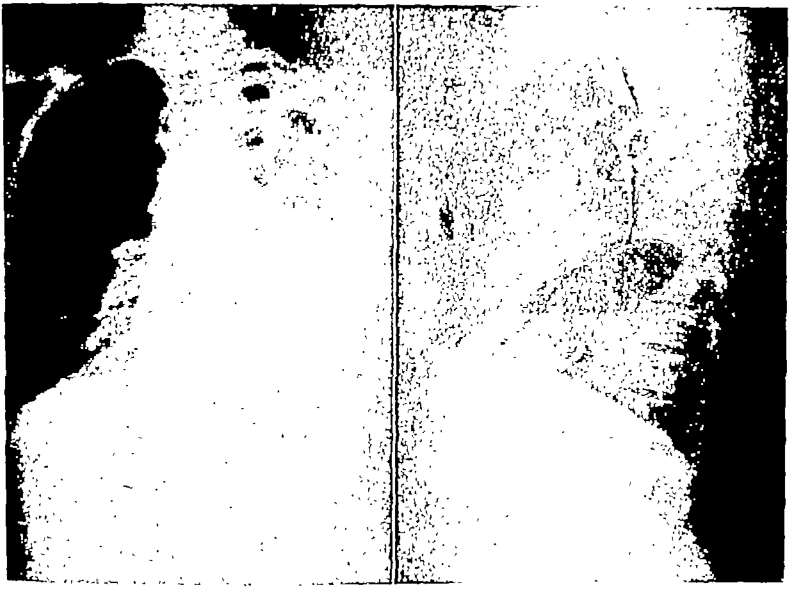

A. *B.*

Fig. 11, *A* and *B*.—Anteroposterior and lateral chest films of a patient with a Lucite ball prosthesis eight months after pneumonectomy. Seventy-five balls were used. There is no overdistention of the remaining lung.

The patients chosen for clinical trial had pneumonectomies for carcinoma. It seemed advisable to try the prosthesis cautiously at first in patients whose life expectancy was short in order to exclude possible unforeseen complications before using it in patients with a longer life expectancy.

The Lucite ball prosthesis has been placed in the pleural cavities of eight patients following pneumonectomy. Inasmuch as when a thoracoplasty is done to prevent mediastinal shift, portions of only seven or eight ribs are usually resected, the pleural cavity has not been completely filled with balls in these patients. The number of Lucite balls used has varied from thirty-five to seventy-five. The patient with seventy-five balls in the left side of the chest was operated upon about eight months ago. Recent x-ray pictures show the mediastinum to be in the midline and no overdistention of the remaining lung (Fig. 11, *A* and *B*). In a smaller individual, thirty-five balls did not fill the pleural cavity but have prevented overdistention of the remaining lung (Fig. 12, *A* and *B*).



A. *B.*

Fig. 12, *A* and *B*.—Anteroposterior and lateral chest film of a patient with a Lucite ball prosthesis six months after pneumonectomy. Only thirty-five one-inch balls were used. The mediastinum is maintained in the midline.

Comment.—Immediately after operation, when the Lucite balls were surrounded by air, one could occasionally hear them rattle a foot or two away from the patient. At that stage, the patient as well often heard the balls rattle. When the air was replaced with fluid, the patients were no longer conscious of the noise. With the stethoscope, however, the rattle may still be heard with each beat of the heart in all of the patients.

There has been no evidence that the balls have caused increased postoperative pain. In two of three patients who complained of more pain than usual, we were able to demonstrate metastatic lesions. The possibility of increased pleural effusion due to the presence of the balls was considered. Thoracenteses were done whenever required to maintain the mediastinum in the midline or slightly toward the operated side. In three of the patients, thoracentesis was never required. Two of the patients were tapped only once or twice. Three of the patients required thoracentesis as late as seven to ten days after operation but it could not be determined whether the presence of the prosthesis played a part in this.

In none of the eight patients has there been any postoperative infection or unusual febrile response. In all of the patients the prosthesis has accomplished the objective of maintaining the mediastinum near the midline. Although we have been looking for possible hazards or complications resulting from the presence of the prosthesis in the pleural cavity, none has yet been apparent. Since the dogs have been observed for only eighteen months and the first patient for only eight months, late complications of foreign body reaction may yet develop.* Our experience to date suggests that the Lucite balls may prove to be an effective and safe substitute for elective postpneumonectomy thoracoplasty.

CONCLUSIONS

1. Lucite balls placed in the pleural cavity of dogs following pneumonectomy prevented mediastinal shift and were well tolerated as evidenced by autopsy studies one year after operation.

2. In eight patients in whom Lucite balls were placed in the pleural cavity after pneumonectomy the mediastinum has remained in the midline and there have been no apparent complications resulting from the presence of the balls.

3. The evidence presented to date suggests that the use of a Lucite ball prosthesis may be a simple and effective method of preventing overdistention of the remaining lung following pneumonectomy.

REFERENCES

1. Cournand, A., and Berry, F. B.: The Effect of Pneumonectomy Upon Cardiopulmonary Function in Adult Patients, Ann. Surg. 116: 532, 1942.
2. Cournand, A., and Lester, C. W.: Pulmonary Function After Adolescence Following Thoracic Surgery, Detroit, Mich., May 29, 1946.
3. Johnson, J., Kirby, C. K., Lazatin, C. S., and Cocke, J. A.: The Use of a Prosthesis to Prevent Overdistention of the Remaining Lung Following Pneumonectomy—A Preliminary Report, Surgery 22: 179-190, 1947.

(See discussion on page 187.)

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*It has now been nineteen months since the first patient was operated upon and no complications have developed. In some of the patients the balls no longer rattle.

AN EVALUATION OF EXTRAPLEURAL PNEUMONOLYSIS WITH LUCITE PLOMBAGE

REPORT OF FIFTY-ONE CASES

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SINCE Tuffier first performed his "pleuroparietal stripping" in 1891, the operation with modifications has been used by thoracic surgeons all over the world. To maintain the collapse effected by extrapleural separation of the parietal pleura from the chest wall, a multitude of substances has been used including air, fat, muscle, paraffin, oil, gauze, cellophane, rubber, fiber glass wool, and many others. The search for the ideal substance goes on.

In 1945 Wilson and Baker[1] found that Lucite (methyl methacrylate) in the form of spheres was inert in the extrapleural space in the experimental animal and maintained satisfactory collapse of the lung. The results of this study were sufficiently encouraging to justify clinical trial.

The first patients selected for operation were "those so-called good chronics in whom thoracoplasty was contraindicated because of low vital capacity, advanced age, bilateral cavities or those who had an unsuccessful thoracoplasty." The simplicity of the operation and the immediate good results appealed to patient and surgeon alike, and many patients refused to have any but the "ball" operation. Also, as experience with the procedure was gained, the indications for operation were broadened to include those patients in whom a thoracoplasty would have been the operation of choice.

A preliminary report by Wilson[2] of the first fifteen patients on whom follow-up study was carried out for six to ten months showed thirteen improved, one unimproved, and one dead. In spite of the early good results, however, Wilson emphasized the experimental nature of the operation and warned against excessive optimism. From January, 1946, to November, 1946, thirty-six additional patients were operated upon by members of the Duke Hospital staff. As late complications began to occur the operation was discontinued in January, 1947, until adequate follow-up studies could be made and the procedure evaluated. This report is based on an analysis of fifty-one cases of extrapleural pneumonolysis with Lucite plombage in white patients operated upon one year and six months to two years and ten months prior to this report. We feel that it is highly important to report our experiences with the operation at this time, for the practice of inserting Lucite spheres in the chest is spreading and may go far before attention is called to its dangers.

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Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

†Dr. Trent died on Dec. 10, 1948.

In Table I are presented the number of operative cases in each age group, their classification, and the type of operation which after a careful review of the clinical history and roentgenograms we feel was indicated in each case. Nearly all of the cases fall within the far-advanced class. All patients except three had bilateral involvement. Twelve patients had had a previous thoracoplasty. Nineteen had bilateral cavities or were suspected of having bilateral cavities. Thirteen patients were considered unsuitable for any type of surgical collapse because of age, extent of the disease, and clinical condition. In only six, in retrospect, would we have considered extrapleural pneumonolysis with plombage.

TABLE I. FIFTY-ONE CASES, THIRTY-FIVE MEN, SIXTEEN WOMEN

AGE (YR.)	NO. OF CASES	CLASSIFICATION			TYPE OF OPERATION INDICATED			
		M.A.*	F.A.†	THORACO-PLASTY	THORACO-PLASTY	REVISION	PLOMBAGE	NONE
20-30	10	3	7	1	7		1	2
30-40	13	1	12	5	6	2	2	3
40-50	16	2	14	5	8	3	2	3
50-60	9		9	1	3	1	1	4
60-70	3		3		2			1
Total	51	6 (11.8%)	45 (88.2%)	12 (23.5%)	26 (50.9%)	6 (11.8%)	6 (11.8%)	13 (25.5%)

*M.A., Moderately advanced.
†F.A., Far advanced.

The technique of the operation has been described in detail previously by Wilson.[2] In the present series the anterior approach was used forty-four times and the posterior approach seventeen times. Three of the patients had a two-stage unilateral procedure while four had a bilateral procedure.

COMPLICATIONS

Complications of the operation may be divided into two groups, those occurring during operation or in the immediate postoperative period, and those occurring several months to years after the initial procedure.

A summary of the early complications may be found in Table II. Thirteen patients had moderate to severe dyspnea which gradually subsided in all except four. In four patients the cavity was entered at the operating table. Only one of these patients survived. In three cases a mediastinal shift was observed. In one of these the spheres were inserted under a thoracoplasty and produced

TABLE II. OPERATIVE AND EARLY POSTOPERATIVE COMPLICATIONS (TWENTY CASES, 39.3 PER CENT)

COMPLICATION	NUMBER	PER CENT
Dyspnea (moderate to severe)	13	25.5
Cavity entered	4	7.8
Mediastinal shift	3	5.9
Spread	2	
Dissection downward of spheres	2	
Compression of superior vena cava	1	
Cardiac failure	1	
Urticaria	1	
Wound separation	1	

only a moderate shift. In the other two which terminated fatally the balls dissected caudally and into the mediastinum. In two patients a postoperative spread of the disease occurred. One patient died of cardiac failure, probably as a result of reduction of the pulmonary vascular bed. In one patient, immediately after operation marked engorgement of the neck and arm veins was noted. He was returned to the operating room and after removal of one sphere the engorgement was relieved. Trial reinsertion of the sphere produced the same engorgement. This phenomenon was thought to be due to compression of the superior vena cava. One patient on the tenth postoperative day developed a generalized urticaria associated with an eosinophilia which subsided spontaneously. In one patient the wound separated before the patient's discharge from the hospital. This patient later developed a bronchocutaneous fistula.

The late complications are summarized in Table III. The tuberculous infections of the extrapleural space were diagnosed by aspiration, the presence of a sinus, or reoperation. Four patients remained dyspneic after operation. Two patients had severe incapacitating chest pain. One of these became a narcotic addict before death; the other developed a tuberculous infection around the spheres two years after operation. In one patient roentgenograms showed the spheres protruding through the mediastinum into the opposite side.

Because of the difficulty in visualizing a cavity in the lung once the Lucite spheres have been inserted, the number of patients with persistent cavities under the spheres cannot be determined accurately even with the aid of laminography. A fluid level in one or more of the spheres is a frequent roentgen finding and may be a source of confusion in attempting to identify cavities. In three patients in whom definite cavities could be seen under the spheres, an attempt was made to remove the spheres preliminary to further surgical collapse or resection. In one case the spheres were so densely embedded that removal was impossible without endangering the patient's life. The attempt was abandoned after five spheres had been removed and the cavity had been entered. In the other two cases the spheres were removed with great difficulty. In each case tuberculous granulation tissue was present between the spheres. One of these patients had a fatal pulmonary hemorrhage a few days after operation, while the other developed a severe tuberculous wound infection. *In five patients the spheres* were removed because of tuberculous infection in the extrapleural space which developed two months to two years after operation. In most of these cases removal was relatively easy, but in two cases all of the spheres were not recovered. One of these patients was subjected to a second operation to recover a sphere

TABLE III. LATE POSTOPERATIVE COMPLICATIONS (SIXTEEN CASES, 31.3 PER CENT)

COMPLICATIONS	NUMBER	PER CENT
Tuberculous infection around spheres	11	21.5
Draining sinus	4	7.8
Spheres extruded beneath skin	4	7.8
Dyspnea	4	7.8
Severe chest pain at operative site	2	
Migration of spheres into mediastinum	1	

TABLE IV. RESULTS IN FIFTY-ONE CASES

AGE (YR.)	IMPROVED	UNIMPROVED	WORSE	DEAD	
				OPERATIVE	LATE
20-30	2	1	2	1	3
30-40	3	1	6	1	3
40-50	3	1	8	3	1
50-60	1	0	2	3	3
60-70	1	0	2	0	0
	10 (19.6%)	3 (5.8%)	20 (39.2%)	8 (15.7%)	10 (19.6%)
Total mortality 35.3%					

embedded in the apex of the lung which could not be found at the first operation. Four of these patients had draining sinuses and one an open wound. One patient who developed a tuberculous infection of the extrapleural space two months after operation had a wound separation and a fatal hemorrhage from the wound.

RESULTS

We have considered as improved those patients who improved symptomatically and who had negative sputum; as unimproved (two patients) those who were not made worse by the operation but who continued to have symptoms and unsatisfactory sputum examinations; as worse those with positive sputum and continued progression of the disease. The complete results are summarized in Table IV. Ten cases can be classified as improved. These will be given in detail. Twenty were definitely worse and seventeen patients died as a direct result of the operation; one patient died two years after operation from coronary occlusion (no autopsy). The corrected late results in forty-two cases are summarized in Table V. Excluded from this table are eight operative deaths and one recovery in which no spheres were inserted following entry of the cavity.

Eight cases in which death occurred from seven to sixty days postoperatively are considered operative deaths. All these patients were poor operative risks, four of them hopelessly ill. In three of these cases the cavity was entered and no spheres were inserted. Death resulted from infection and respiratory failure. In three cases the spheres were removed six to eight days after operation because of marked dyspnea. One patient died as the spheres were being removed on the tenth day. Another patient died of circulatory failure attributed to a reduction in size of the pulmonary vascular bed.

Of the ten late deaths which occurred from two months to two years postoperatively, four resulted from respiratory failure, one from hemorrhage from

TABLE V. CORRECTED RESULTS IN FORTY-TWO CASES*

AGE (YR.)	IMPROVED	UNIMPROVED	WORSE	DEAD
20-30	2	0	2	3
30-40	3	1	6	3
40-50	3	1	8	1
50-60	1	0	2	3
60-70	1	0	2	0
	10 (23.8%)	2 (4.7%)	20 (47.6%)	10 (23.8%)

*Eight operative deaths and one recovery in which no spheres were inserted following entry of the cavity are excluded.

a wound which had opened as a result of tuberculous infection in the extrapleural space, one from a pulmonary hemorrhage after an operation for removal of the spheres, one from respiratory failure and progression of the disease, and one from a coronary occlusion.

Of the fifty-one cases, fourteen were considered to have definite bilateral cavitation while five others were suspected of having cavities on the opposite side. Of this group with bilateral cavities, only four had a bilateral procedure. One of these patients was considered improved (Case 4), one died, and the other two had persistent cavities under the spheres. Bilateral procedures were not done in the remainder, with the exception of one case, because of death or dyspnea. One patient diagnosed by laminography as having bilateral cavities had a unilateral procedure only (Case 1). The sputum converted and is reported to have remained negative since operation.

Eleven patients had had a previous thoracoplasty and one a bilateral thoracoplasty. Of these, seven had spheres inserted under the thoracoplasty. Two of these improved (Cases 1 and 2). Of the five who had spheres inserted on the opposite side, one improved (Case 10). Five of the twelve patients died and two became worse.

Of the six patients in whom we thought extrapleural pneumonolysis with plombage was indicated as the primary procedure, three improved, one had a tuberculous wound infection, and two died.

Bronchoscopy was done on six patients before operation and only one had findings suggestive of endobronchial tuberculosis. An attempt was made in our follow-up study, however, to do bronchoscopy on all patients who would consent. Of the eighteen patients on whom bronchoscopy was carried out, to date, twelve had ulcerative tuberculous tracheobronchial disease.

No effort has been made to draw conclusions from vital capacity studies. We have found the recorded figures to be inconsistent and frequently unreliable and have therefore excluded them from the study.

IMPROVED CASES

CASE 1.—J. B., a 49-year-old white man, had a bilateral three-rib thoracoplasty in 1942, followed by a revision on the right and removal of three more ribs in 1944. He was readmitted in July, 1945, with positive sputum. Planograms revealed bilateral cavitation and bilateral thoracoplasty. Extrapleural pneumonolysis with plombage was indicated. An anterior procedure was carried out on the right with insertion of fifteen spheres. Despite the fact that cavitation was present on the left, a bilateral procedure was not done since the sputum converted after the first operation. He has since been discharged from the sanatorium and is now working but has had no recent roentgenograms. The sputum is reported to be consistently negative on culture.

CASE 2.—C. L., a 45-year-old white man, had a two-stage, six-rib thoracoplasty in 1944. The cavity remained open. He was admitted to Duke Hospital in 1945 for revision. Classified as: right thoracoplasty with residual cavity, left F.A. A revision of the thoracoplasty was indicated. In July, 1945, anterior extrapleural pneumonolysis was performed under the thoracoplasty with insertion of sixteen spheres. Five months later, because of a persistent cavity, thirteen additional spheres were inserted through a posterior incision. Subsequent roentgenograms did not show a cavity and there was no progression of the disease. The patient had one positive sputum examination in March, 1947, but subsequent cultures were negative. The patient is now working as handy man in a Chicago hospital.

CASE 3.—W. H., a 42-year-old white man, was admitted to Duke Hospital in November, 1945, with cavitation on the right. Classified as: right F.A. with cavity, left M.A. A thoracoplasty was indicated. Through a posterior thoracoplasty incision the third and fourth ribs were removed, an apicolysis was performed, and an unknown number of spheres were inserted. The first two ribs were left intact in order to prevent deformity of the chest and to prevent pressure on the nerves and vessels by the spheres. A second stage was performed and the fifth, sixth, and seventh ribs were removed. The sputum was positive on discharge from the sanatorium in November, 1947, but subsequent specimens were negative on smear and culture. Clinically he is doing well. He refuses bronchoscopy.

CASE 4.—V. K., a 32-year-od white woman, was admitted to Duke Hospital in November, 1945, with roentgen evidence of bilateral cavitation. She had had one positive gastric washing in 1942, but had never had a positive sputum. Classified as: right F.A. with cavity, left M.A. with cavity. In this case we should have recommended thoracoplasty on the right with extrapleural pneumonolysis later on the left with paraffin or oil plombage. She had bilateral anterior procedures with the insertion of fifteen spheres on each side. Discharged from the sanatorium one year ago, she is now beginning to work. Bronchoscopy in February, 1948, revealed no endobronchial tuberculosis. Sputum has never been positive. Roentgenograms showed no progression.

CASE 5.—K. Y., a 61-year-old white woman, was admitted to Duke Hospital on Dec. 20, 1945, with cavitation in the right apex. Classified as: right F.A. with cavitation, left M.A. A thoracoplasty was indicated. An anterior procedure on the right was carried out with insertion of twenty-seven spheres. She improved clinically but is slightly dyspneic and continues to have a moderately productive cough. Single sputum specimens on two occasions were negative on culture.

CASE 6.—M. E., a 21-year-old white man, was admitted to Duke Hospital in February, 1946. Roentgenograms revealed cavitation in the right apex. Classified as: right M.A. with cavity, left M.A. A thoracoplasty was indicated. An anterior approach was done with insertion of forty-nine spheres. Subsequent roentgenograms showed no progression of the disease; there was no evident cavity. Sputum examinations have been consistently negative. The patient is now working and asymptomatic.

CASE 7.—C. P., a 21-year-old white woman, was admitted to Duke Hospital in February, 1946, for surgical collapse of a persistent cavity in the left apex. Classified as: right M.A., left F.A. with cavity. A thoracoplasty was indicated. An anterior procedure was done on the left with insertion of thirty-three spheres. She developed tuberculous meningitis eight months postoperatively, but gradually recovered with the aid of streptomycin. She is still on strict bed rest, but the sputum has been repeatedly negative on culture and symptomatically she is improved.

CASE 8.—E. M., a 42-year-old white woman, was admitted to Duke Hospital in February, 1946. Roentgenograms revealed a cavity with a fluid level in the right apex. Classified as: right F.A. with cavitation, left M.A. A thoracoplasty was indicated. An anterior procedure was performed, but the number of spheres inserted was not recorded. Sputum remained negative on smear and concentrate since discharge from the sanatorium one year ago and is now asymptomatic and doing regular housework.

CASE 9.—E. D., a 58-year-old white woman, was admitted to Duke Hospital in February, 1946, with cavitation on the right. Classified as: right F.A. with cavity; left clear. A thoracoplasty was indicated. An anterior procedure was performed with the insertion of forty-two spheres. Follow-up was done at the Florence-Darlington Sanatorium, Florence, S. C., and the patient is reported as ''clinically well and sputum negative.''

CASE 10.—P. M., a 31-year-old white man, had a two-stage thoracoplasty on the left in 1943, followed by an anterior stage in 1945. Roentgenograms on admission at Duke Hospital in May, 1946, revealed a cavity in the right apex. Classified as: right F.A. with cavity, *left thoracoplasty. Planograms revealed no evident cavitation on the left.* Extrapleural pneumonolysis with plombage was indicated. An anterior procedure was done on the right; seventy-two spheres were inserted. He had some dyspnea after operation. Planograms in December, 1947, revealed no evident cavitation. Sputum was negative on culture. The patient is now at home on limited exercise. He refuses bronchoscopy.

COMMENT

Extrapleural pneumonolysis with plombage is a desirable operation because it can be done in one stage, it is technically easy in the majority of cases, the patients tolerate it well, there is no deformity of the chest, the function of good lung tissue is maintained, and the hospital stay is short.

It is not surprising, therefore, that repeated attempts have been made to find the ideal material for insertion in the extrapleural space to maintain pulmonary collapse. It is not surprising also that these attempts have failed regardless of the type of material used, largely because of the susceptibility of the extrapleural space to infection; but of the many substances employed for this purpose, air,[3] oil, and paraffin[4] have been the most successful; their use, however, is limited to highly selected cases in which thoracoplasty is not indicated. Experimental studies at first seemed to indicate that Lucite spheres approached the ideal plombage substance because of their ease of introduction and their inertness in the body, but clinical trial has failed to substantiate the early promise of the operation.

Attention has been called in a previous report[1] to the dense hyaline tissue which forms around the spheres in the experimental animal. We found this to be true also in three clinical cases without preoperative evidence of infection in which we electively removed or attempted to remove the spheres from the extrapleural space. Since Lucite has been shown to be an inert material in the body the probable explanation for this phenomenon lies in the spherical shape of the plastic material which allows sufficient space between the spheres for serum to accumulate, clot, and organize. Once this dense hyaline mass has formed it is very difficult to remove the spheres it encases unless infection and liquefaction of the surrounding tissue occur. Removal of the spheres post mortem in one case required a mallet and chisel. It appears, therefore, that Lucite plombage in some cases must be a definitive procedure. If it is not successful in a given case, frequently no other procedure, such as thoracoplasty or resection, is feasible since the success of such an operation is dependent upon removal of the spheres.

Early results of the operation of Lucite plombage as performed at Duke Hospital[2] were encouraging but Wilson was careful to call attention to the fact that "too few cases had been completed and that too short a period of time had elapsed since operation to evaluate the results of this form of collapse therapy." The late results presented in our report emphasize the cogency of this warning when dealing with such a disease as tuberculosis.

Although our late results do not justify the continued use of Lucite spheres in the extrapleural space, it is possible that subsequent reports from other institutions may show that Lucite has, like paraffin and oil, a limited usefulness as a plombage material.

SUMMARY AND CONCLUSIONS

1. Fifty-one cases with operation a minimum of one year and six months to two years and ten months prior to this report have been presented in which extrapleural pneumonolysis with Lucite plombage was attempted or carried out. Ten patients (19.6 per cent) improved, three (5.8 per cent) did not improve, twenty (39.2 per cent) became worse, and eighteen (35.3 per cent) died.
2. Lucite plombage in some cases must be a definitive procedure, for once the spheres are inserted they are, in our experience, extremely difficult to remove unless the surrounding tissue is liquefied by infection.
3. The late results of the operation as performed at Duke Hospital do not justify continuation of the procedure.

REFERENCES

1. Wilson, D., and Baker, H.: Experimental Surgical Pulmonary Collapse, Surg., Gynec. & Obst. 82: 735-742, 1946.
2. Wilson, D.: Extrapleural Pneumonolysis With Lucite Plombage, J. THORACIC SURG. 17: 111-122, 1948.
3. Reid, Hugh: Extrapleural Pneumothorax in the Treatment of Pulmonary Tuberculosis, Thorax 1: 211-238, 1946.
4. McIndoe, R. B., Steele, J. D., Jr., and Alexander, John: Extrapleural Pneumonolysis With Paraffin Filling, Am. Rev. Tuberc. 40: 243-254, 1939.

(See discussion on page 187.)

EXPERIMENTAL AND CLINICAL STUDY OF COLLAPSE THERAPY USING FIBERGLAS WOOL AND FABRIC

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COLLAPSE therapy is a well-established method of treatment in pulmonary tuberculosis. The simplest and most effective type of collapse therapy is artificial pneumothorax. Far from complete success is attained because of the high incidence of pleural adhesions. Even when they are completely severed by pneumonolysis, the lung may exhibit a tendency toward re-expansion. This is often initiated by the attendant pleural reaction which incites an obliterative process.

A selective type of collapse would seem to be the ideal, whereby only the diseased portion of the lung is collapsed. The undiseased portions are allowed to remain expanded in order most efficiently to carry on the functions of respiration.

True selective collapse is seen to occur in only a small percentage of cases and, at that, it is certainly not at the deliberate design of the pneumotherapist, but rather by virtue of the relative physiologic relationships existing between the several lobes. Selective collapse may be considered as occurring when the diseased lobe is in a state of peripheral atelectasis (associated with a relative bronchial hypotension), whereas, the remaining lung tissue exhibits a marked tendency to remain inflated.

When this selective condition does not prevail, collapse of the diseased areas also involves collapse of a part or all of the undiseased areas and thereby denies the patient a sizable portion of good respiratory tissue. Efforts to produce deliberate selective collapse have been made. Thoracoplasty has been used extensively with a considerable degree of safety, but this always results in a severe degree of physical deformity and the end results are not too gratifying.

Extrapleural pneumonolysis has been efficient in bringing about good anatomic selective collapse, but this procedure has been handicapped by a high incidence of space infection as well as some tendency toward re-expansion too early. Attempts to combat these complications have resulted in the introduction of a variety of space-filling agents in the belief that an obliterated space would be unfavorable for the development of infection.[1] Air, saline, oil, paraffin, body tissues, plain gauze, methyl methacrylate (Lucite), and others have been used.[2, 3, 4] Most of these agents are capable of maintaining the accomplished collapse, but each has demonstrated certain undesirable features which are invariably related to the physical, chemical, or physiologic properties of the agents used. In short, because of heaviness they produce pressure necrosis,

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soft agents tend to become liquefied, those that are unyielding result in penetration into lung parenchyma, irritating agents give rise to infection, and, as in the case of body tissues, these are too difficult to mobilize in sufficient enough quantities to be of value.

In the search for more suitable materials, two Fiberglas[*] products have been examined. One is a Fiberglas wool product grossly resembling raw cotton. The other is a woven fabric made from Fiberglas.

This is a material which is inorganic, nonallergenic, pliable, nonhygroscopic, noncombustible, and is light in weight, one cubic foot weighing 0.3 to 0.5 pound.[†]

In an attempt to evaluate the ability of animal tissues to tolerate these materials as foreign bodies over a period of time, two series of experiments were undertaken.

In one, Fiberglas wool was placed in the extrapleural space of each subject in a series of fifteen dogs. The dogs were subsequently sacrificed and specimens were taken from the implanted areas. The duration in time of these implantations ranged from one week to eight months. On gross examination, adhesions were usually noted occurring between the parietal and visceral pleura immediately adjacent to the implanted Fiberglas. Fifty per cent showed moderate to occasionally severe giant-cell foreign body reaction, and all showed either thickened pleura or fibrinous deposition, indicating considerable tissue reaction encountered in the use of raw Fiberglas wool.

The second group of experiments was carried out on fourteen dogs, in which Fiberglas fabric was applied directly to the intact pleural surfaces in the form of a bag to encompass a single lobe. First, the selected lobe was encouraged to become atelectatic, then, a sheet of Fiberglas fabric was fashioned about the lobe so as completely to contain it and prevent its re-expansion. Compression of the hilar structures was avoided. The dogs were sacrificed at intervals and specimens were obtained at ½, 1, 4, 5, and 6 months. Upon gross examination, the Fiberglas covering was found in place, undisturbed, showing no adherence to the parietal pleura. The cloth was held in close apposition to the visceral pleura by an adherence which was very fine and permitted extreme ease in removal by peeling, leaving a clean, shiny pleural surface, even at 6 months. In five unselected cases, efforts at re-expansion of these lobes were immediately successful by applying positive pressure through the dog's endotracheal tube. On microscopic sectioning of the remaining nine of these lobes, there was seen in all cases an excellent atelectasis with patent bronchi. It was usual to see a minimal mononuclear infiltration and a very mild pleural reaction. The absence of fibrosis in even the oldest specimens is indicative of a reversible condition.

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[*] Fiberglas; T. M. Reg. U. S. Pat. Off. OCF Corp.

[†] The Fiberglas superfine wool is composed of glass fibers random-oriented in a batt. Fiber diameter averages .00006 inch. The fabric, known as "116 cloth," is .004 inch thick and is of balanced Fiberglas 450-½ yarns, 60 ends per inch in warp and 58 per inch in the fill. Each strand is formed of approximately 200 individual filaments. The average filament diameter is approximately .00022 inch.

Late postoperative x-ray studies were made on five dogs and showed good collapse of the treated lobes and normal x-ray appearance of the untreated lobes.

Comparable procedures were carried out on a series of patients in order to achieve selective collapse.

CASE REPORTS

CASE 1.—N. W., a 26-year-old white woman, was admitted May 13, 1948, with a history of known pulmonary tuberculosis since June, 1943. Pneumothorax was instituted on the left at that time and the patient became symptom-free until September, 1947, at which time x-ray showed development of tuberculous involvement in the right upper lobe. Bed rest was instituted and the lesion became more extensive; a cough developed during the past six weeks. Physical examination revealed a thin, 85 pound, white woman in no distress and presenting findings of pneumothorax on the left. Chest roentgenogram demonstrated the left partial pneumothorax and also tuberculous infiltration of the right upper lobe with the presence of a central area of cavitation. On May 14, 1948, through the fifth rib bed an open pneumonolysis with Fiberglas covering was done. The patient made a rapid postoperative recovery, and smears on three occasions for acid-fast bacilli were negative.

CASE 2.—J. D., a 28-year-old white man, was admitted Oct. 13, 1947, a diagnosis of pulmonary tuberculosis having been made in 1943. The patient received right pneumothorax in 1946 and this was shortly discontinued as ineffectual. Examination revealed a fairly well-developed and well-nourished young man in no distress. There were absence of breath sounds below the fourth rib on the right, and crepitant râles were heard in the area of the scapula. X-ray showed infiltration with cavitation in right upper lobe, and free fluid in the right base. On Oct. 22, 1947, an open pneumonolysis was done through the right fifth rib bed and the upper lobe was encompassed in Fiberglas fabric. The patient made a rapid postoperative recovery and the sputum was converted to negative.

CASE 3.—H. H., a 34-year-old white man, was admitted Feb. 26, 1948, having been ill since 1943; a diagnosis of pulmonary tuberculosis had been established in 1947. Pneumoperitoneum was instituted in February, 1947, because attempts at pneumothorax were unsuccessful. The patient had 33 hemoptyses in early 1948 and was admitted in that state. Examination revealed a thin, pale, young, white man in no great distress. There were râles over both anterior apices and left posterior upper lung fields and a friction rub was heard over the latter. X-ray showed pneumoperitoneum and dense infiltration in the left upper lobe with several cavities in evidence. On Feb. 27, 1948, an open pneumonolysis was done. The upper lobe resisted satisfactory collapse because of the caseous pneumonic infiltrative process resident in the parenchyma. Collapse of the lobe was about 60 per cent, nevertheless the lobe was wrapped with Fibergas fabric and the remaining two lobes were allowed to re-expand to fill the residual space. The patient made a rapid immediate postoperative recovery, had no recurrence of hemoptyses, and gained ten pounds in weight in the following three months. The sputum, however, continued positive. This type of patient represents a poor choice for any type of collapse therapy, and should rather have been allowed resection of the lobe.

CASE 4.—W. B., a 36-year-old white man, was admitted Jan. 15, 1947, having had a diagnosis of pulmonary tuberculosis four years prior to admission. Pneumothorax had been unsuccessfully attempted on the right. Physical examination revealed a fairly well-developed and nourished white man in no distress. X-ray revealed infiltration in the right upper lobe with cavitation, and also a dense infiltration in the left hilar region. On Jan. 17, 1947, a right extrapleural plombage was done by first lining the extrapleural space with Fiberglas fabric and then filling the resultant fabric sac with Fiberglas wool. This modification over the animal experimentation was done to protect the surrounding tissues from the irritation found to be caused by the raw or uncovered Fiberglas wool.

The patient made a rapid postoperative recovery and, although the sputum is still positive, the Gaffky count is lower and there is seen on x-ray considerable clearing of the contralateral disease. The patient is asymptomatic.

CASE 5.—J. P., a 31-year-old white man, was admitted on Oct. 24, 1947, for check-up relating to a marked increase in dyspnea and the increasing tendency to turn a blue color with exertion. Past history revealed that he had been a "sick baby" at birth, and that he had always been troubled with shortness of breath since he could remember. In recent months he had noted swelling of the ankles when doing limited light work. Physical examination showed a well-nourished and developed young man in no distress when resting. There was a marked blue cyanosis of the lips, tongue, and nail beds. There were no râles heard in the chest. The heart was enlarged and there was a systolic thrill over the entire precordium. There was a loud, grade 4, systolic murmur present. Respiratory function tests, angiocardiography, and routine x-rays strongly intimated the diagnosis of (1) pulmonary tuberculosis, bilateral upper lobe, and (2) aplasia of the right ventricle, associated with hypoplasia of the pulmonary artery, and double superior vena cava. Therefore, reasoning that a single stage operation should be sufficient to afford major relief for both the pulmonary disease and also the cardiovascular anomaly, on Dec. 19, 1947, an open pneumonolysis was done through the fifth rib on the right and a Blalock operation was done, anastomosing the right subclavian artery to the hypoplastic right pulmonary artery. The patient's immediate postoperative course was excellent. Coughing, straining, or walking no longer produced the extreme blue cyanosis—it was no longer present. However, due to bronchial hypertension, associated now with pulmonary arterial hypertension, it very soon became impossible to keep the upper lobe collapsed as was intended at the time of operation in order to control the pulmonary disease on the worse side. Therefore, on Jan. 16, 1948, an extrapleural pneumonolysis was accomplished, the space lined with Fiberglas fabric to protect the surrounding tissues, the sac filled with Fiberglas wool, and the wound closed in the usual manner with good healing. The sputum remained positive, not surprising in view of the active disease in the contralateral side. The patient was referred to a local sanatorium for a regimen of medical therapy.

CASE 6.—M. W., a 45-year-old white woman, was admitted on March 13, 1948, known to have had pulmonary tuberculosis since 1945. The patient had been on routine sanatorium care and because of the extent and nature of the lesions, intrapleural pneumothorax was judged as impossible, and she was admitted for surgical treatment. On examination there was seen a well-developed, obese (188 pounds), middle-aged woman, looking much older than her stated years, but in no distress. X-ray showed bilateral upper lobe chronic fibroid tuberculosis with multiple cavitation bilaterally, more extensive on the right. There were persistent râles heard over the left upper lung fields. On March 19, 1948, an extrapleural pneumonolysis was done through the right fourth rib and the space lined with Fiberglas fabric and then filled with Fiberglas wool, as was done in the previous cases. Table I shows the pulmonary function studies before and after this operation. The patient made an uneventful recovery, except that there was noted a too great collapse of the lung due to overfilling of the space. Thus, on April 9, 1948, the old scar was incised down to the neck of the Fiberglas

TABLE I. M. W., 45 WF

	ADMISSION	APRIL 8, 1948	MAY 8, 1948
Actual vital capacity	2,550.0 c.c.		1,250.0 c.c.
Respiratory rate (per min.)	11.0	13.0	12.0
Tidal air (liters)	0.609	0.490	0.417
Resting minute ventilation	6.7	6.3	5.01
Maximal breathing capacity	43.2	45.9	29.54
Ornsteen factor	6.4	7.2	5.8
Oxygen rebreathing bag	10.5		10.1
Carbon dioxide rebreathing bag	5.0		7.62

sac, the sac was opened, and about one-half of the previously inserted glass wool was removed. At the same time, a first stage thoracoplasty with removal of the first and second ribs was carried out on the left (contralateral) side. The patient made an uneventful recovery, so, on April 28, 1948, the thoracoplasty was completed with the removal of the third, fourth, and fifth ribs. Again, recovery was uncomplicated and Table I gives the pulmonary function figures. The patient showed no more dyspnea at discharge than she did on admission. The sputum was converted to negative.

CASE 7.—J. G., a 38-year-old man, was admitted April 9, 1948, dating his illness from 1937. A diagnosis of pulmonary tuberculosis had been established in 1938. Pneumothorax was instituted on the left. In 1941 a six-rib thoracoplasty had been done. He was admitted for surgical treatment of a reactivated lesion in the left upper lobe. Examination revealed a well-developed and nourished young man in no distress. There was evidence of a right thoracoplasty with a well-controlled underlying lung lesion. There were persistent râles heard through the left upper lung fields. X-ray showed a right thoracoplasty with no evidence of tuberculous activity. The left lung field showed evidence of a thickened pleura with tuberculous infiltration in the upper lobe. On April 17, 1948, an extrapleural pneumonolysis was done on the left. The space was lined with Fiberglas fabric and the sac filled with Fiberglas wool, in the same manner as the preceding cases. The patient made an uncomplicated and rapid recovery, and it is too early to evaluate the sputum conversion.

CASE 8.—T. C., a 59-year-old white man, was admitted Sept. 22, 1947, his third admission. A diagnosis of pulmonary tuberculosis had been made in 1938. In November, 1946, a thoracoplasty had been done on the right side. This was unsatisfactory so in February, 1947, a revision was done with the introduction of raw Fiberglas wool into the extrapleural space in the hope of gaining a better collapse. It is noteworthy that this is the only case in which the Fiberglas wool was not covered with Fiberglas fabric to protect the tissues. Soon there developed a draining and infected sinus in the revision scar. In the meantime, several attempts at pneumothorax on the left were made without success. Physical examination revealed an emaciated white man in no acute distress. There was bronchial breathing in the left middle lung fields. The right posterior thorax showed a well-healed thoracoplasty revision scar with a small draining sinus. X-ray revealed a right thoracoplasty with no apparent active disease in the right lower lobe. There were mottled densities in the left upper lobe suggestive of cavitation. On Sept. 24, 1947, the sinus tract was excised along with the previously deposited raw Fiberglas wool, which was now in the form of a fibrofatty tissue mass measuring 20 by 10 by 2.5 cm. On microscopic section there was seen extreme fibrosis with many foreign body giant cells, which contained colorless fibrils. The wound healed per primam and the patient was discharged to sanatorium care.

CASE 9.—H. I., a 34-year-old white man, was admitted April 1, 1947, pulmonary tuberculosis having been diagnosed in 1945. Pneumothorax was attempted without success on the right. Examination revealed a well-developed and nourished man in no distress. There were râles in the right upper lung fields. On April 2, 1947, an extrapleural pneumonolysis was done on the right and the space was lined with Fiberglas fabric; this sac was filled with Fiberglas wool. The patient made a rapid recovery and the sputum was converted to negative and has so remained to the present.

CASE 10.—R. S., a forty-three-year-old white woman, was admitted May 12, 1948, for surgical treatment of bilateral pulmonary tuberculosis, known as present since 1928. The patient had been treated in a number of institutions, experiencing many remissions and exacerbations. Bilateral pneumothorax, right phrenemphraxis, and pneumoperitoneum were all abandoned as unsuccessful. On physical examination, the patient was well developed and nourished and presented râles over both upper lung fields with percussion dullness in the extreme apices. Chest roentgenograms showed upper lobe involvement with suggestion of bilateral cavitation. On May 19, 1948, extrapleural pneumonolysis was done on the left, with instillation of Fiberglas fabric lining packed with Fiberglas wool in the usual manner. The postoperative course was uneventful. It was contemplated to do the opposite side within a two-week period.

TECHNIQUE

For both types of operations the patients are given a general anesthetic using the endotracheal tube and placed in the lateral horizontal position. A curved periscapular incision is made and carried through the superficial back muscles to expose the costal cage. With the scapula translated superoanteriorly, a section of the fourth or fifth rib is removed. When the use of Fiberglas cloth wrapping is intended, the pleura is opened and an intrapleural open pneumonolysis is done. The lobe is rendered atelectatic and a sufficient amount of cloth is cut to allow complete investment of the collapsed lobe. The free edge or periphery is infolded and sutured around the circumference of the lobar hilum with interrupted No. 40 cotton. This is accomplished in a gathering manner so as to provide a snug but not tightly constricting covering.

When the use of plombage is desired, an extrapleural stripping is carried out in the standard manner. Then, the space so created is completely lined with one layer of Fiberglas fabric with the neck of the cloth sac presenting at the wound. This sac is then filled without resorting to tight packing and the neck of the sac is sutured shut. In both operations a drainage tube is left in place with suction for twenty-four to forty-eight hours to prevent accumulation of fluid incident to the operative trauma. The patients have all been ambulatory within twelve to twenty-four hours, restricted only by the limits of the tubing.

DISCUSSION

The indications for these procedures would seem to be the same as for any type of lesion in which one would expect favorable response to permanent collapse therapy of a selective nature. The problem of overdistention of the uninvolved lung tissue might give concern in the use of the Fiberglas wrapping. This concern, however, should not be any greater than that appreciated in the normally occurring sequence of pathologic changes seen when lesions of any type heal. This healing is attended by fibrosis and sometimes extensive contraction which always lays open the contiguous normal lung tissue to compensatory emphysematous changes.

It is too early to evaluate the proper placement of these procedures in the treatment of tuberculosis. Other techniques have made their entry showing good promise, only to fail due to certain inherent faults, which in the course of time precipitated late complications. Caution is therefore advocated in the use of these procedures until more evidence is at hand concerning the limits of usefulness and the development of possible complications. Encouragement is gained from the early results and it is hoped that a continuing favorable follow-up will justify extension of this project.

SUMMARY

Experimental studies were undertaken using a combined series of twenty-nine dogs in which two procedures were done. In one, extrapleural Fiberglas raw wool packing was affected. This resulted in tissue reaction which was regarded as unsatisfactory. In the second series, Fiberglas fabric was used intrapleurally to invest a selected lobe. This was found satisfactory in so far as excellent selective atelectasis was accomplished, and also that the implantation of this material occasioned only a minimal tissue reaction. The case histories of ten patients were reviewed. In three, the upper lobes were wrapped in Fiberglas fabric to accomplish selective collapse. Seven had extrapleural pneumonolysis and filling of the created space with Fiberglas wool. One of these had the raw wool alone placed in the space and this resulted in the same kind of tissue reaction as seen in the dogs in which there was considerable foreign body response, and this became infected and had to be removed. The remaining six had the spaces first lined with Fiberglas fabric which was shown in the dogs to be practically nonreactive, and then the lined space was filled with the raw Fiberglas wool. No infections resulted in these and the collapse was regarded as satisfactory.

We wish to express our thanks to the Owens Corning Fiberglas Corporation, for their assistance, and to Dr. G. F. Froio for his work on the pathologic studies. We are also indebted to Dr. Martin Entine who first suggested the use of Fiberglas as a prosthetic agent.

REFERENCES

1. Wilson, D. A., and Baker, H.: Surg., Gynec. & Obst. 82: 735, 1946.
2. Dolly, F. S., Jones, J. C., and Skillen, J.: J. THORACIC SURG. 8: 646, 1939.
3. Dolly, F. S., Jones, J. C., and Skillen, J.: Am. Rev. Tuberc. 41: 423, 1940.
4. Matson, R. C.: Am. Tuberc. 39: 162, 1938.

DISCUSSION ON "THE CLINICAL USE OF A PROSTHESIS TO PREVENT OVERDISTENTION OF THE REMAINING LUNG FOLLOWING PNEUMONECTOMY" BY DR. JULIAN JOHNSON, DR. CHARLES K. KIRBY, DR. C. S. LAZATIN, AND DR. J. A. COCKE*; "AN EVALUATION OF EXTRAPLEURAL PNEUMONOLYSIS WITH LUCITE PLOMBAGE," BY DR. JOSIAH C. TRENT, DR. JAMES D. MOODY, AND DR. JOSEPH S. HIATT, JR.†; AND "EXPERIMENTAL AND CLINICAL STUDY OF COLLAPSE THERAPY USING FIBERGLAS WOOL AND FABRIC" BY DR. THOMAS J. E. O'NEILL, DR. HECTOR P. REDONDO RAMIREZ, AND DR. ROBERT G. TROUT

DR. WILLIAM R. RIENHOFF, JR., Baltimore.—I have enjoyed the papers very much indeed, but there are two points I would like to comment on. In the first place, I think the term "compensatory emphysema" is an inappropriate one and used rather loosely. Emphysema is a pathologic condition which denotes fragility of the elastic tissue in the alveolar septa, together with rupture of alveolar walls and confluence of alveoli. This is not a compensatory mechanism but a pathologic change. What is meant, and the correct term seems to me to be used, is "compensatory dilatation" of the remaining lung following total pneumonectomy. In 1935,‡ I believe, in conjunction with Heuer and Reichert, a series of experiments were performed to prove what happened to the remaining lung following total pneumonectomy in the dog. This experimental work showed conclusively that the remaining lung undergoes a compensatory dilatation following removal of one lung which dilatation is confined to the definitive respiratory unit, composed of the ductus alveolaris, atria, and alveoli, there being no changes in the main bronchi and not the slightest evidence of the pathologic condition emphysema, as just defined.

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*See page 164 for article by Johnson, Kirby, Lazatin, and Cocke.

†See page 173 for article by Trent, Moody, and Hiatt.

‡Rienhoff, William F., Jr., Reichert, Fred L., and Heuer, George J.: Bull. Johns Hopkins Hosp. 57: 373-383, 1935.

In various autopsies, including the first case done at the Johns Hopkins Hospital by me in 1933 for fibrosarcoma of the lung (the patient drowned five years following operation), and in another instance, a woman of 70, who died six months after operation due to cerebral metastases, section of the lung at autopsy showed no evidence whatsoever of emphysema, but established unquestionably the compensatory dilatation that was found to exist experimentally. Also, there has never been any evidence of right ventricular hypertrophy following total pneumonectomy. Therefore, I think the term ''compensatory emphysema'' should not be used, but instead, ''compensatory dilatation.''

The second point that interested me particularly in Dr. Johnson's remarks was the fact that Lucite balls were used to obliterate the thoracic cavity following total pneumonectomy for malignant tumors. It is my opinion that compensatory dilatation of the remaining lung following removal of one lung for malignant tumor should not be prevented, therefore, the use of plombage is contraindicated. This may not, and probably does not, apply to total pneumonectomy for tuberculosis, because dilatation of the remaining lung might lead to a tendency to spread of the disease in that remaining lung. However, that is not true of compensatory dilatation in the remaining lung following total pneumonectomy for nonspecific infections such as diffuse bronchiectasis or infected multilocular cysts. In a series of more than 200 cases of total pneumonectomy, mainly for malignant tumor, but also for inflammatory conditions, we have not found it necessary to use any form of intrathoracic plombage and have felt that the reason our patients have had a minimal amount of impaired cardiorespiratory function is that there was a maximum opportunity for the remaining lung to undergo compensatory dilatation. The follow-up study at the present time is being continued and will be reported at a later date.

The very fact that after operation patients having a total pneumonectomy for one reason or other are somewhat short of breath even though in an oxygen tent, but later are able to breathe perfectly well and not only perform their vocations but as well their avocations, would seem to indicate that compensatory dilatation is physiologically very helpful rather than harmful. Therefore, any method employed to discourage or impair this compensatory dilatation, it seems to me, would have a deleterious effect upon the patient.

DR. H. R. DECKER, Pittsburgh.—I enjoyed these papers very much. I have had no experience with the new products used as packs after extrapleural pneumonolysis but I have had some experience with paraffin pack, a rather small series to be sure, but interesting to me because I was able to trace the cases through a period of from eight to fifteen years. In a group of 16 cases in which I used paraffin pack, for apical cavitation and bilateral tuberculosis, there are 3 patients surviving now for periods of eight, thirteen, and fifteen years, and apparently perfectly well. I will show later the slides of these cases and discuss them a little more fully. I have a feeling from hearing the paper by Dr. Trent and his co-workers that they have discarded Lucite as the medium for holding the extrapleural pneumonolysis down. I am sure the figures published through the literature with reference to paraffin pack are better. The difficulty, however, is this: Almost all figures that one reads in the literature cover a follow-up period of not more than five years. Most of them are just for immediate postoperative periods or less than three years. I am sure, therefore, that the figures as published will deteriorate as time goes on. It is so in my own small series. For instance, the series of 16 patients, in which the pack was used for tuberculosis, shows only 3 known to be living and well. Eleven are known to be dead over a period of from one to four years following the use of the pack. The cause of death mainly is progressive tuberculosis.

I would like to show two or three slides of these patients who are surviving today after the use of the pack.

(Slide 1.) The patient was not in very good physical condition and we suggested this procedure. This is the picture taken immediately after the operation.*

(Slide 2.) The man was admitted to my care following persistent hemorrhage in 1933. It seemed that the paraffin packing might be sufficient to stop the hemorrhage, and it did.

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*The second slide shows the pack after eight years, the apical cavity closed. The patient is clinically well of tuberculosis.

This patient was discharged in 1937 as being well. This picture was taken two months ago. He worked four years in Czechoslovakia on his farm and then as a prisoner in a German agricultural camp. He is now on his way to a farm in Oregon, apparently entirely recovered and having no symptoms from the pack still in place.

DR. J. B. GROW, Denver.—I was very impressed with these papers, although when we consider the operation of extrapleural pneumonolysis we must consider an operation which has not found a great place in treatment of tuberculosis. At the same time there are many instances in which there is no other procedure to be offered the patient. These were well outlined by Dr. Trent. There is no real competition between thoracoplasty and plombage in the patient whose condition is suitable for thoracoplasty. However, for the patient not suitable for thoracoplasty, plombage offers the only procedure which will satisfactorily control the disease. As Dr. Trent said, the advantages of plombage are: (1) Any portion of the complete lung may be collapsed. (2) Pulmonary function is preserved. (3) A one-stage procedure is done instead of multiple procedures. (4) The economic factors, hospitalization and expense, are reduced. (5) Following plombage there is no paradoxical motion and a decreased incidence of spread. (6) Last, and least important, plombage is not deforming.

Our experience with plombage is based on 53 cases at the National Jewish Hospital in Denver, and 26 private cases. The cases at the National Jewish Hospital are better followed, and those are the ones I will present. Of the 53 cases, 78 per cent of those over six months following operation have a negative sputum. There was one death, which occurred in a patient who had a congenital heart ailment, a high blood count, and resulted from cerebral thrombosis.

I think it is important in considering the subject, to consider the technical features, because apparently the results are largely dependent on two factors. First, the selection of cases, and second, the technique of operation.

(Slides.) The anterior approach as described by Graham and Joannides is used. An incision is made along the anterior axillary line; the second rib is resected and the cleavage plane established between endothoracic fascia and chest wall. From an anterior approach, since most tuberculous cavities are posterior, one can dissect the lung from the chest wall under direct vision, in the adherent area. The importance of thorough dissection of the mediastinum should be emphasized. As Dr. Trent pointed out, extrapleural plombage may have to be a definitive procedure unless the lung can be dissected away from the mediastinum. When the pneumonolysis includes stripping of the upper lobe from the mediastinum, it is possible to do a lobectomy or some other type of resection under the Lucite plombage, leaving the Lucite in place.

The next patient shown had a rather thorough pulmonary function study. In spite of advanced disease he had a 124 liter per minute maximum breathing capacity, which is considered quite good. Following bilateral plombage, his maximum breathing capacity was 114 liters per minute, a very slight reduction. He still has a positive sputum and is being considered for resection of the right upper lobe under the Lucite.

The next patient was a social worker for the hospital. Following a first-stage thoracoplasty there was suppurative bronchitis and spread of the disease to the lower lobe. The entire lung became atelectatic and, in spite of repeated attempts at bronchoscopic aspiration and re-aeration of the lung, the lung remained collapsed. Normal weight was 132 pounds; she was down to 82 pounds and slipping very fast in spite of streptomycin. With the experience of these previous cases it was thought possible to carry out a rather extensive procedure on a desperate risk patient. An extrapleural pneumonolysis of the entire lung was done in one stage.

To the present time, four lobectomies and one pneumonectomy have been performd subsequent to extrapleural pneumonolysis and Lucite plombage. Pulmonary resection leaving the plombage material in place is a technically satisfactory procedure. If extrapleural pneumonolysis is done, it is important to strip the lung from the mediastinum in order to make subsequent resection possible in those patients in whom the disease is not controlled by the collapse therapy.

DR. O. C. BRANTIGAN, Baltimore.—Following the work of Dr. D. Wilson and Dr. J. Johnson I have been very much interested in Lucite ball plombage in the treatment of pulmonary tuberculosis and Lucite ball prosthesis after pneumonectomy.

The report on Lucite ball plombage by Dr. Trent is extremely discouraging. It is difficult to justify his early morbidity and mortality but the late results are difficult to challenge with our present state of knowledge. I now have completed plombage on 29 patients suffering from pulmonary tuberculosis. There have been no complications nor untoward effects. The first operation was done about one year ago. I do not have statistics on end results since it is too early to consider seriously the end results.

I vary with Dr. John Grow only on technical points. The posterior approach is preferred rather than the anterior or lateral. The apex of the lung should not be freed from the mediastinum. If left adherent to the mediastinum there will be better drainage of the bronchi and the disease thus cannot be displaced into good lung tissue and remain uncollapsed.

In considering Lucite ball prosthesis after pneumonectomy, or thoracoplasty after pneumonectomy, there are two distinct problems—one is the cardiorespiratory function and the other is the flare-up of tuberculosis after pulmonary resection for tuberculosis. For patients who have had pneumonectomy for nontuberculous disease, as advocated by Dr. Rienhoff, I have done neither thoracoplasty nor prosthesis and the results have been entirely satisfactory. If cardiorespiratory difficulty arises one can do a thoracoplasty or prosthesis. In patients who have had pneumonectomy for tuberculosis the problem is different. If one waits for a flare-up of the disease, it is usually too late for treatment. An adequate thoracoplasty after pneumonectomy is a formidable procedure. In the last ten patients, through a small incision, under local anesthesia, Lucite ball prosthesis has been done four to ten weeks after pneumonectomy. The fifth such patient developed a *Staphylococcus aureus* empyema and subsequently died. The remaining nine patients have had no difficulty, but the follow-up is short since the first was done in October, 1947.

DR. STUART W. HARRINGTON, Rochester, Minn.—I am very reluctant, and am certain most of us are, to put a foreign body into the chest cavity or any part of the body, as a matter of fact, where it is to be permanent. However, there are cases in which the remaining chest cavity will require thoracoplasty, and I think it advisable that we explore these means by which we may avoid thoracoplasty to avoid overdistention or mediastinal shift which may be troublesome to the patient.

My associate, Dr. Clagett, has been particularly interested in developing a prostheses for the chest cavity following pneumonectomy. He has given me a résumé of the work he has done in this field to the present time, which, with your permission, I will read:

"Recently, Dr. Small, Dr. Grindlay, and I reported on the use of gelatin foam sponges to fill the pleural cavity after pneumonectomy. We have carried out extensive studies on animals and have used the material clinically in 20 pneumonectomies. We believe this material has considerable merit, but it is gradually absorbed and since it causes no tissue reaction or fixation, does not accomplish any permanent benefit. Experience with plastic polythene in various forms such as tubes for replacement of defects after tracheal resection, tubes for repair of stricture of the common duct, and sheets for replacement of dural defects, has demonstrated that this material causes little tissue reaction, is elastic and flexible, and can be molded or worked into various forms and shapes. We were encouraged to try the use of this material for prostheses that could be used to occupy the pleural space left after pulmonary resection. Bags, roughly lung shaped, were made of this material and were loosely filled with Pyrex glass fiber. This resulted in a soft, flexible, and very lightweight prosthesis, which has some elasticity but which will retain its shape. Such bags were placed in the empty pleural cavity after pneumonectomy in a series of dogs. Neither mediastinal shift nor pleural effusion has occurred in these animals. Pleural reaction consists of only a slight degree of thickening. Roentgenographically these bags are almost invisible.

There have been no indications of any physiologic disturbance. The postoperative course and condition were much better than in the control dogs which underwent pneumonectomy without insertion of the prosthesis. Exploratory thoracotomy two and three months after pneumonectomy has shown only slight thickening of the pleura and at most, only a few centimeters of clear sterile fluid.

"This study on dogs has been in progress only a few months, and while it has been going on, another series of experiments has been carried out in rats. The rats have had one lung removed and the empty space filled with a prostheses. These rats have been killed at various times postoperatively, and the pleural reactions studied. Briefly, much less fluid and exudate than usually follows pneumonectomy was found, and this fluid contains fewer cells; the pleural cavity surface and the bag are early surrounded by a soft membrane of fiber. At first the membrane is relatively thick, but within two months it is only a thin layer of fiber. The tissue is not adherent to the bag; the bag can be removed without difficulty.

"There are some technical difficulties in the manufacture of these bags in the desired shapes and sizes. We hope to be able to develop sizes and shapes to correspond to the various segments of lung as well as the entire lung, in the near future. If these prostheses work out in long-term studies on animals as well as they have thus far, we believe such prostheses may have a useful place in thoracic surgery."

As I have said, we all hesitate to use prostheses but there are occasions in which I think they may have to be used, in order to avoid thoracoplasty.

DR. A. M. VINEBERG, Montreal.—I should like to draw your attention to a procedure which we are now using at the Grace Dart Hospital, Montreal, which we think is worth while because we use a living fascial suture, or shall we say a living fascial sheet. We take a fascial sheet from the leg and sew it across the chest after depressing the apex of the lung as is done in extrapleural pneumothorax. We suture it to the fifth interspace and on the mediastinal side we suture the fascia to the lung on its mediastinal side. In this way we hope to keep the apex of the lung down, and in the few cases in which we have used this treatment, it has been successful. I should like to show you one example of this procedure.

In subsequent cases we have placed the fascial sheet dirctly on the apex, and in this way have produced what nature often produces, a thickened part over the lung which we wish to collapse.

DR. LYMAN BREWER, Los Angeles.—I should like to report briefly on a small series of cases in which Dr. Dolley and I have used the Lucite ball plombage with a very limited indication. We have not employed Lucite balls as a primary plombage in place of extrapleural pneumothorax, but have reserved this technique for bad risk cases where thoracoplasty had failed. In these patients although pulmonary resection might have converted the sputum, such an operation was not possible due to contralateral disease or poor general condition. This includes a group of 31 patients, over 35 years of age, who had vital capacities around 1,000 to 1,500; five had severe diabetes. No attempt was made to pick ideal cases as we were interested to see what this procedure would do. These patients have been treated in the period from the past three to fifteen months.

The technique of operation was simple. The operative thoracoplasty wound was opened, a small extrapleural space was developed, and the Lucite balls were placed in this space. We did not free the mediastinum as has been recommended earlier this morning. It is really too early to consider the results in these cases, but we have had 15 negative cultures. In analyzing our failures, we find that bronchial stenosis, tuberculous tracheobronchial disease, and cavity elsewhere in the lung have been mainly responsible for failure to convert the sputum. In addition we have gained the preliminary impression that certain giant tension cavities, and lobes almost totally destroyed by tuberculous disease, are not suitable for extrapleural Lucite pack following unsuccessful thoracoplasty. In some cases, too, it was impossible to get adequate separation of the lung. (Slides.)

The majority of the cases reported this morning, I believe, have been mainly ones in which the Lucite ball plombage has been used primarily in place of extrapleural pneumothorax. This represents a group of patients in whom the pulmonary disease was not as well stabilized as those in our group in which considerable fibrosis of the lung was present after thoracoplastic collapse. It seems to be a reasonable preliminary conclusion that the lung in which exudative disease is present with little pulmonary fibrosis does not tolerate well an extrapleural Lucite ball plombage, while the more stable fibrotic lung following thoracoplasty will tolerate such a plombage.

We believe, therefore, in cases where pulmonary resection is not feasible following unsuccessful thoracoplasty, further trial of extrapleural Lucite plombage is definitely indicated.

DR. C. W. LESTER, New York.—It has been my privilege to have been associated with Dr. André Cournand and his staff in the study of pulmonary function after pneumonectomy, particularly in children. It is our feeling that overdistention is a condition to be reckoned with and should be avoided. Our first studies one or two years after operation made us think that perhaps overdistention was not a factor where children were concerned. Several years later we restudied the same patients after they had passed the age of puberty and had become adults, and we found overdistention was something to consider and that pulmonary function was definitely less good in those who had distention than in those who did not. We therefore thought that some method should be attempted to prevent distention of the lung while these children were growing. Thoracoplasty, in a child, of course, is a very deforming operation. We had not thought of Lucite, but of course most of the operations that I have done were in infected cases. Here suppurative lungs are being dealt with, and infection in the presence of a foreign body is something to be avoided. We therefore have tried a modified form of thoracoplasty which really is not a thoracoplasty at all. In opening the chest the fifth rib is removed completely, and then the fourth and sixth are removed in their posterior halves. What we hope to obtain by this is that, as the child grows, the upper part of the chest will contract, and the rising diaphragm will prevent overdistention at least until the child reaches adult life when a thoracoplasty can be accomplished without so much deformity. We are, of course, studying these children as we go along.

(Slides.) These two cases are very recent. We cannot draw conclusions from them as yet. One was an 8-year-old who had extensive bronchiectasis of the left lung with contracture of the lung and shift of the right chest into the left side. After operation in which the fifth rib can be seen resected completely and the fourth and fifth partly resected, the heart has moved back into the right side of the chest and there is much less distention. This child was too young to attempt functional study; oxygen saturation was normal in the blood.

The other child had essentially the same condition. After operation some shift can be seen, not very much. We found on functional study the residual air was 25 per cent, which is essentially normal, and the results have been good so far.

DR. J. D. MURPHY, Oteen.—When a stone is dropped into the placid surface of a millstream, there is set in motion a series of centrifugal waves which ultimately cover the whole pond. So, when the first Lucite ball was dropped into the extrapleural space at Duke University, Oteen being geographically close to Duke was early in contact with this wave of patient enthusiasm and we succumbed. Having had some unfavorable experiences during the extrapleural pneumothorax era of 1938 to 1939, we determined to screen our cases carefully and attempted to select, therefore, only those cases we decided were good thoracoplasty risks.

(Slides.) I will give you briefly our experience. There were 22 cases in all; 14 primary operations and 8 operations following thoracoplasty in which the cavity had not been closed. There was sputum conversion in 27.7 per cent, which does not approach that of thoracoplasty. There were 3 empyemas and 3 fistulas in the primary group; 1 empyema in the secondary cases and in 2 patients migration of the balls. In 1 patient 5 balls migrated into the mediastinum. They are still there and we are unable to find them. In one patient a ball migrated up to the neck and produced pressure on the brachial plexus and subclavian arteries. That was removed. We have removed a total of 9 packs. In cases in which empyema follows and the material is liquefied, it is not difficult. In cases in which there has not been empyema each ball is enclosed in a fibrous capsule, presenting a honeycomb-like structure. These are more difficult to work with, but can be removed without too much trouble. A uterine tenaculum forceps has been used to remove several deeply embedded balls. We have had no mortality. We started these operations in September, 1946, and became so discouraged by 1947 that in June we discontinued them. We will wait awhile before other plombage materials are tried.

DR. FRANK S. DOLLEY, Los Angeles.—It has become evident in listening to the several uncorrelated papers that have just been delivered on the subject of the introduction of Lucite balls between the lung and the chest wall for the local collapse of lung tissue affected by tuberculosis, that some attempt should be made to evaluate the things that have been said of this particular form of treatment.

My associate, Dr. Brewer, has just reviewed our results in the use of the Lucite pack. From these results we are more than ever encouraged in the use of Lucite balls. In other papers the operation has been uniformly condemned. The reason for this divergence in opinion is due, I am certain, to the selection of cases.

In all our cases except one, we have established a Lucite pack following thoracoplasty. We resect a small portion of the rib immediately beneath the thoracoplastic area, and find the line of cleavage at that point. After a small pocket is obtained by digital dissection, the space is enlarged, under direct vision by use of a Cameron light. By sharp and blunt dissection the lung and parietal pleura are freed from the immediately overlying tissues. Parenthetically, it should be said that we wait from two to three or four months following a manifestly unsuccessful thoracoplasty before we introduce the Lucite balls. For, by so doing, we are certain that the parietal pleura is sufficiently solid to minimize the danger of a pulmonary slough from ball pressure. We carefully avoid freeing the apex of the lung, for we want the pressure to be entirely lateral.

For the first three or four days following this procedure, but seldom longer than one week, the patient is often conscious of the clicking of balls in the chest when he moves around or coughs. After that time, I do not believe there has been a case where a patient has been conscious of ball movement.

On two occasions we have removed the balls several weeks after insertion. One because of pressure against a bronchus, which caused an almost constant harassing cough. This was relieved after some of the balls were removed. The other occasion was because of postoperative, nontuberculous infection. In both these cases, the sputum continued negative by culture.

We have had no deaths, and no complications that we have not been able to relieve. Our laboratory reports show 50 per cent negative sputum by culture in our series. We have used the Lucite pack only in cases where thoracoplasty has proved unsuccessful, and there seemed nothing else which offered a reasonably good chance for conversion of the sputum.

So I say, as I did in the beginning, that instead of being discouraged with the results we have obtained, we look upon the Lucite pack as a definite addition to our series of surgical procedures directed toward the cure of pulmonary tuberculosis. As in the choice of any operation for this disease, the important thing is the choice of the case selected for the particular operation contemplated.

DR. ROBERT KLOPSTOCK, Jamaica, N. Y.—I should like to make two technical remarks and one recommendation. If one has to resort to any extrapleural compression therapy using air or foreign body of a proved substance, this type of procedure should be carried out only if the pleural space has been tested for firm obliteration, prior to the operation. Extrapleural plombage is recommended as an operation of minimum trauma in cases with limited reserve. The perforation likely to occur into the pleural space if it has been free prior to operation may be a very grave complication, particularly in patients with limited reserve. The other technical point that I should like to make is that the extrapleural space should be absolutely dry, tested for being free of oozing before the foreign material is placed into it. Exudate in the plombage bed can exert prohibitive pressure upon the mediastinum and by mobilizing the plombage itself creates "the floating" ineffective plombage.

The recommendation, which may sound dissenting, would be to regard the plombage as a temporary procedure. One should remove the plombage, irrespective of substance used (even if the result proved to be satisfactory) between six or eight weeks to six months after operation and to follow it up at the same time with a limited apical thoracoplasty. The plombage, a limited surgical procedure if performed with delicate care, served its purpose by creating a very selective collapse. In order to secure the permanency of this selctive collapse it seems to be safer to replace the plombage with just a limited apical thoracoplasty than to rely on the plombage itself, for the foreign material stimulates the formation of a continuously shrinking fibrous capsule around itself. The slow shrinkage can exert a considerable pressure within the capsule. The least resistant point outside of the capsule is the surface of the damaged lung toward which the late perforations are likely to occur due to the protruding of the plombage substance if the plombage has not been removed in time. Late perforations may occur from six months up to two or more years following operation.

DR. TRENT.—I should like to say in closing that certainly we agree with Dr. Decker that the longer the cases are followed the poorer are the results. Our follow-ups, I should like to remind you, although not very long, have continued for a minimum of one and one-half years, the longest approximately three years. I have one slide I should like to show you, which illustrates one type of case included in the Duke Hospital series. Some of these cases like the one Dr. Brantigan illustrated, were selective, in that the area immediately over the cavity, which is approximately under the second rib in this case, were selected for collapse and the lung allowed to remain attached to the mediastinum. (Slides.)

This was done approximately two years before this report. The pictures show the patient approximately one year after operation and immediately after operation. When the patient was discharged the sputum was negative. While at home he resumed activity, had no symptoms, and was feeling well. We considered this a good result. A few months ago he began to develop symptoms and felt he should return for check-up. He returned two months ago and the film on the right was made. The smear was found loaded with acid-fast organisms two years after operation.

AN ANALYSIS OF VARIATIONS OF THE SEGMENTAL BRONCHI OF THE RIGHT LOWER LOBE OF FIFTY INJECTED LUNGS

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INTRODUCTION

NOTWITHSTANDING the general acceptance in this country of the Jackson-Huber terminology of the bronchopulmonary segments, and in the British Empire of the somewhat differently named but corresponding zones, there seems not to have been made, as yet, a statistical study of the variations of the lower lobe segments. Brock (1946) discussed these from the standpoint of the varying amount of territory a given segment can cover and published excellent figures of some of these injected specimens. However, there still remains the task of analyzing variations in the light of an empirically established prevailing pattern, that is, of determining the typical surface area of a segment and then noting how often, and by what other bronchi, this is supplied in whole or in part. Such an analysis would seem to be a necessary preliminary to accurate localization of lesions of the lung and to surgical resection of its segments.

The present study is restricted to the segments of the right lower lobe, but a companion article (by Berg, Boyden, and Smith), dealing with the segments of the left lower lobe, together with a summary of the differences between the two lobes, is being prepared for publication.†

MATERIAL AND METHODS

Fifty fresh specimens of right lower lobes have been used in this study. The technique of injection was that employed by Scannell (1947). After the hilar region had been freed of vessels and lymph nodes, the primary branches of the right lower lobe stem were dissected from the surrounding parenchyma for a distance of about 1.5 cm. In many instances the level of primary branching of each segmental bronchus was reached also. Following partial inflation with air to clear the passages, each segment was injected with hot colored gelatin at approximately 85° C. The colored gelatin was prepared by dissolving 75 Gm. of U.S.P. gelatin and 10 Gm. of potassium iodide in 500 c.c. of tap water at 100° C and adding 4 c.c. of appropriate vegetable dye to each 100 c.c. of gelatin. Simple aniline dyes available at the grocery store were used.

Immediately after injection of each segment, the lobe was plunged into cold tap water to aid in the gelling of the segment. After two minutes it was removed from the cold bath and another segment injected. Midway through the process the intersegmental margins, as revealed by the colored masses, were drawn on the surface with India ink. This step was repeated, following the completion of the injection process, but this time the surface of the lung was carefully dried with toweling, and under an electric fan, both before and after

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†For comparable analyses of the left and right upper lobes, see Boyden and Hartmann (1946), Scannell (1947); Boyden and Scannell (1948), and Scannell and Boyden (1948).

application of the ink. In this manner the intersegmental boundaries were preserved permanently.

After drawings were made of the anterior, posterior, and diaphragmatic views of each lung, the segmental bronchi and rami were dissected in order to check and correlate the pattern of the bronchial tree with that of the surface distribution of the injected gelatin. The fact that the lungs were solid masses of gelatin made this step much more difficult than would have been the case if one were dissecting lungs preserved by the usual embalming methods, but the essential points could be determined in each case. After the tree was in full view and drawn for the record, the stem was opened and the location of the bronchial orifices noted on the drawing.

The terminology employed in designating the bronchopulmonary segments is that proposed by Jackson and Huber (1943). The numerical designation of branches is that devised by Boyden (1945).

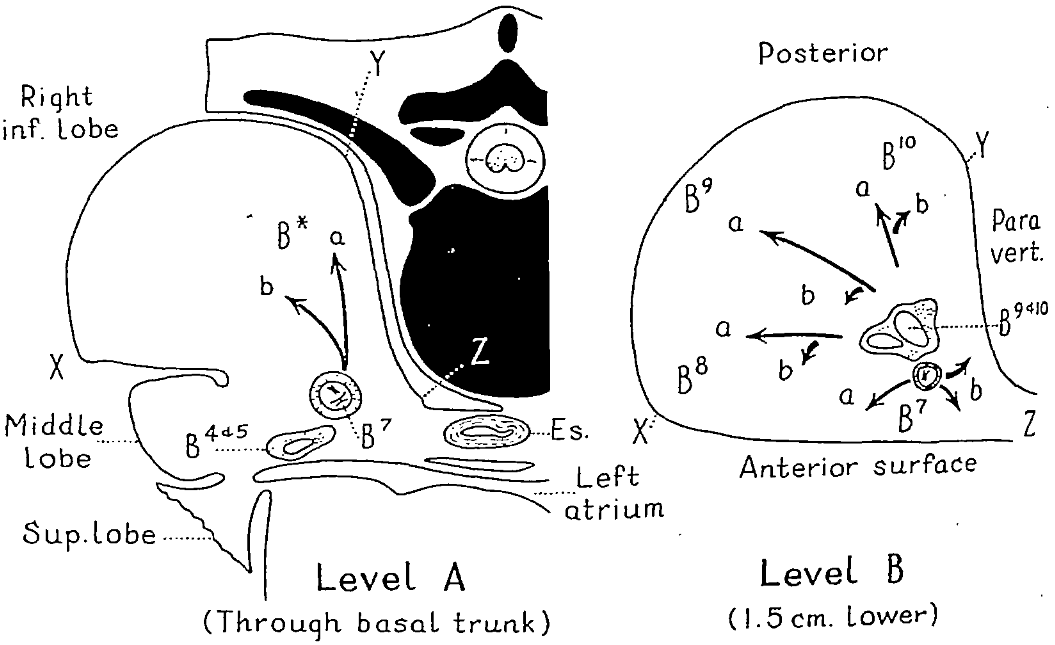

Fig. 1.—Transverse sections of right lower lobe at two levels: *Level A*, section just below orifice of superior segmental bronchus (B^6). to show origin of subsuperior bronchus (B^*) from common stem of $B^{8, 9+10}$; the branches of B^* are so lettered as to correspond to the overlying branches of B^6 (see Fig. 3). *Level B*, section just below origin of B^*, to show sectors of the lung supplied by the four basal bronchi (B^7, B^8, B^9, B^{10}. *X*, interlobar margin, separating anterior (interlobar) from costal surface of lobe; *Y*, costoparavertebral margin, separating paravertebral from costal surface of lobe; *Z*, pulmonary ligament, separating anterior from paravertebral surface. Arrows, at *Level B*, indicate direction of bronchi. The *b* branches of B^8, B^9, B^{10} are descending toward the diaphragm. Note that B^7a supplies the anterior surface, B^7b the paravertebral (and anterior) surface.

THE GROSS CONFIGURATION OF THE RIGHT LOWER LOBE

The right lower lobe somewhat resembles a cone that has been flattened anteriorly and medially, left rounded on its posterior and lateral side, and then telescoped from below. It thus presents four surfaces—a slightly curved anterior surface flattened by the upper and middle lobes, a paravertebral surface lying against the vertebral column and grooved by the esophagus, a costal surface molded by the curving ribs, and a concave diaphragmatic surface indented by the dome of the liver. As seen in cross section (Fig. 1) the anterior and costal surfaces are separated by the right-angled interlobar margin (X), the costal and vertebral surfaces by an obtuse costoparavertebral margin (Y), and the anterior and paravertebral surfaces by the hilum and pulmonary ligament (Z).

The *costo-paravertebral margin* is barely noticeable in a fresh specimen, but it has been arbitrarily indicated by a line in the figures on the right side of Plates 1 to 4 (see Plate 1 for designation), since the position of the segments cannot be defined easily without such a landmark.

The *interlobar margin* is shown in the figures on the left side of Plate 1. This is the edge which marks the posterior border of the interlobar or oblique fissure. As pointed out by Brock (1942), this fissure begins at the fifth rib or the fifth interspace (one segment lower than is usually described in the anatomic texts) and follows the sixth rib down to the diaphragm.

The *anterior* (or interlobar) *surface* is not a flat plane but is often gently curved. Superiorly, as the lobe thins out and becomes nearly semicircular in cross section, the anterior surface faces somewhat laterally. This portion is usually fused in varying degree with the posterior segment (B^2) of the upper lobe. (See Plates 1 and 4, No. 40 and 49.) Inferiorly, the anterior surface faces more medially and is characterized by a fossa which we have termed the sulcus of the *inferior* vena cava (Plate 1) to distinguish it from the fossa for the superior vena cava which carries the anatomic term, sulcus venae cavae. The former is also a substantial groove. This was recognized by Braus (1924), who gave it the vernacular German name of *Delle*.

Laterally, the inferior portion of the anterior surface is crossed by the middle lobe. The lower border of the middle lobe usually passes from the hilum toward the lower lateral angle of this anterior surface. (See line separating subsegments B^8b and B^7a in specimen No. 39, Plate 4.) The position of this inferior margin of the middle lobe is not marked by any ridge or groove on the anterior surface of the lower lobe, nor have any of the fifty specimens presented a fusion of the middle lobe along this line. However, the proximal end of the middle lobe frequently fuses to the lower lobe at the inferior or lateral margins of the hilum (see No. 40, Plate 1).

The superior margin of the middle lobe coincides with the *interfissural crest* (Plate 1) which separates the surfaces on the inferior lobe that are covered, respectively, by the upper and the middle lobe. This line usually coincides with the division between upper and lower portions of the inferior lobe, the upper half representing the distribution of the superior segmental bronchus (B^6) and the lower half the zone supplied by the two basal segmental bronchi (B^{7+8}).

THE SUPERIOR SEGMENTAL BRONCHUS (B^6)

The superior segmental bronchus is the first posterior branch of the right lower lobe stem and is situated just inferior to the level of the orifice of the middle lobe bronchus and nearly opposite to it. It has three principal rami (Fig. 2, *A*): a medial (B^6a), a superior (B^6b) and a lateral (B^6c).* This does

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*The medial is the paravertebral ramus of Brock (1943). It was originally designated the posterior ramus by Boyden (1945), but the additional information obtained in this study suggests that medial is more accurate than posterior. Also, in conformity to the method of numbering branches of the right lung in counterclockwise order, the letters designating these rami have been revised.

EXPLANATION OF PLATES

(Sketches rendered for publication by Lawrence B. Benson)

Sketches of injected fresh specimens of the right lower lobe of the lung, showing distribution of *segmental* bronchi. The large drawings on the left side display the anterior or interlobar surface; those on the right side, the costal surface as viewed posteriorly (X⅓). The smaller figures represent the diaphragmatic surface (X⅙).

Color scheme: *Yellow color,* segment supplied by superior bronchus (B^6); B^6a, b, c, distribution of its medial, superior, and lateral rami. *White color,* segment supplied by subsuperior bronchi (B^* and/or BX^*). *Blue color* (anterior surface), segments supplied by medial basal bronchus (B^7); a, b, distribution of anterior and medial rami. *Red color,* segment supplied by anterior basal bronchus (B^8); a, b, distribution of lateral and basal rami. *Blue color* (costal surface), segment supplied by lateral basal bronchus (B^9); a, b, distribution of lateral and basal rami. *Green color,* segment supplied by posterior basal bronchus (B^{10}); a, b, laterobasal and mediobasal rami. (The highest branch of B^{10} (BX^*) is left uncolored when it supplies the subsuperior zone.)

Plate 1.—*Specimen 43,* The superior segment (B^6) is typical as to size, angle of placement, and distribution of rami. The subsuperior segment (B^*) is typical in position (except that it is pushed somewhat laterally by the invading ramus of B^7) but it belongs in that small group (14 per cent) in which the segment is supplied only from level 2 of the stem bronchus, that is by a subsuperior proper (B^*). In this case, the bronchus arises just above the orifice of B9. The basal segments are typical except that the medial basal bronchus (B^7) is defective: although originating at its usual place, it consists of a medial ramus only (B^7b); the apparently missing anterior ramus (B^7a) is represented by an accessory branch (BX^7a) of the anterior basal, hence the latter (B^8) appears to extend atypically as far as the sulcus of the inferior vena cava.

Specimen 40, The superior segment (B^6) occupies the upper half of the lobe. Posteriorly, the lateral ramus (B^6c) predominates, and its displaced deep branch (‡) invades the subsuperior region (for normal deep branch, see Figs. 2*A* and 3). The subsuperior segment is thereby displaced somewhat laterally. It is supplied by the high dorsal branch (BX^*) of the posterior basal (B^{10}). The basal segments are atypical in that B^9 is absent as such, being represented by BX^9b, an accessory ramus of B^8b. Consequently in this specimen, the anterior basal segment extends more posteriorly than usual. B^7b fails to reach the diaphragm.

Plate 2.—*Specimen 48,* The superior segment (B^6) occupies an upper wedge-shaped zone of the lobe. Both it and the posterior basal segment (B^{10}) are shortened by the unusual paravertebral extent of the subsuperior segment. The latter is supplied by three bronchi—one subsuperior proper (B^*) which arises just beneath the orifice of B^7, and two accessory subsuperiors (BX^*) which arise several centimeters lower down from $B^{10}a$ and $B^{10}b$. The lateral basal segment (B^9) is shortened by the unusual spread at B^8a.

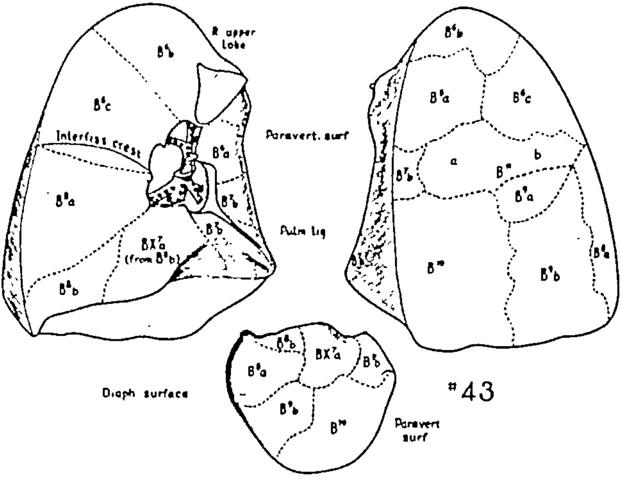
Specimen 42, The superior segment (B^6) occupies an oblique half or less of the lobe. Again ramus B^6c predominates posteriorly. The subsuperior segment is a small mid-posterior zone supplied by BX^* (10). The medial basal segment (B^7) is demarcated by a deep fissure which extends to the center of the diaphragmatic surface. The anterior basal (B^8) is anomalous in that while its bronchus arises from the usual position it consists of the lateral ramus only (B^8a). (This, in turn, has an accessory branch [BX^6c] which takes over part of the territory above the interfissural crest, that is, the zone usually supplied by the superior bronchus, B^6.) The basal portion of the anterior basal segment (BX^8b) is taken over by an accessory branch of the lateral basal bronchus (B^9).

Plate 3.—*Specimen 50,* The superior segment (B^6) is obliquely placed. In contrast to that of Specimen 40 (Plate 1) the segment in this specimen descends further anteriorly than posteriorly. Also B^6c predominates posteriorly. The subsuperior segment is supplied by two subsuperiors proper, the first B^* arising midway between the orifices of B^8 and B^*, the second B^* just above the orifice of B^9, yet, curiously enough, they terminate side by side. Because of the low origin of the second B^*, the accessory subsuperior (BX^*) was presumably forced to distribute much lower than usual; for this reason it has not been included in the subsuperior segment although its designation has been retained. This is also the only specimen encountered in which the lateral branch (B^9a) of the lateral basal segment reached the diaphragm. Otherwise, the basal segments are typical.

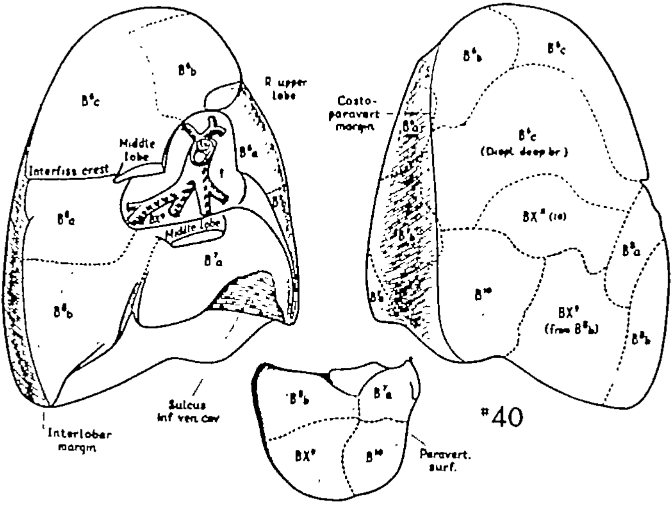
Specimen 46, This and No. 42 (Plate 2) illustrate that 38 per cent of specimens in which the subsuperior segment is supplied only by the BX^* ramus of B^{10}. It differs from that of No. 42 in that it extends into the paravertebral area. The other segments are typical.

Plate 4.—*Specimen 39,* This is the only specimen encountered in which there were two subsuperior bronchi arising exclusively from the stem of the posterior basal (B^{10}). Only the upper one, however, may properly be considered as supplying the subsuperior segment. Also, this specimen resembles No. 42 (Plate 2) in that B^8a takes over a portion of the superior segment by virture of its accessory ramus, BX^6c. It differs in that B^8b is normal in origin and not a branch of B^9 as in No. 42.

Specimen 49, This is the only specimen encountered in which the anterior basal segment (B^8) existed as a separate lobe. As shown in diaphragmatic view, the segment consisted of a cleft lobe which seemed to have protruded from its position between the medial basal (B^7) and lateral basal segment (B^9). This specimen is also the only one encountered which had a distinct cleft between superior and basal segments. It is also peculiar in the extent to which the superior segment is fused to the upper lobe.

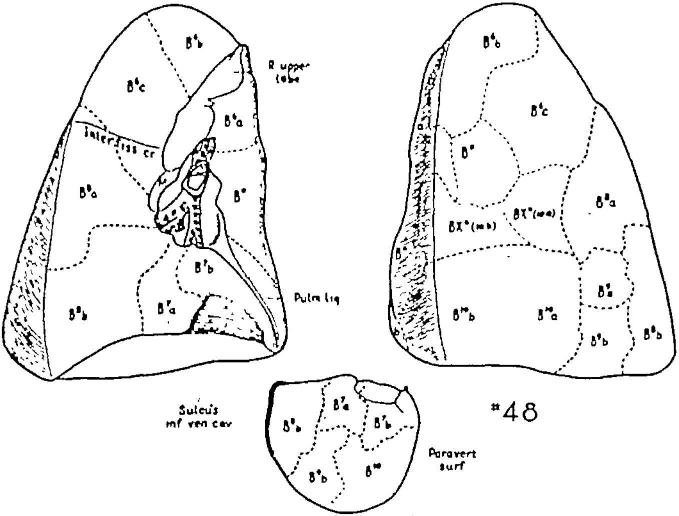

R upper Lobe
B^6b
B^6c
Interfiss crest
Paravert. surf
B^6a
B^8a
B^7b
Pulm lig
BX^7a (from B^8b)
B^7b
B^8b
B^6b
B^6a
B^6c
B^7b
a
b
B^*
B^9a
B^{10}
B^9b
B^8a
B^8b
BX^7a
B^7b
B^8a
Diaph surface
B^9b
B^{10}
Paravert surf

#43

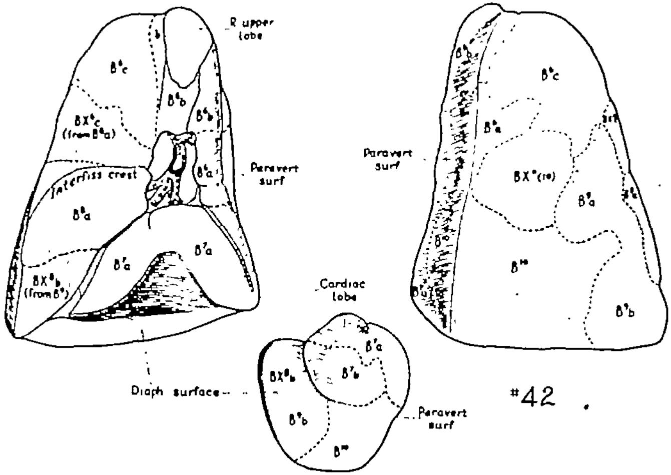

B^6b
R upper lobe
B^6c
Middle lobe
Interfiss crest
B^6a
B^7b
B^8a
BX^9
Middle lobe
B^7a
B^8b
Interlober margin
Sulcus inf ven cav
B^6b
B^6c
Costo-paravert margin
B^6a
B^6c (Diaph deep br)
BX^9 (10)
B^7b
B^8a
B^{10}
BX^9 (from B^8b)
B^8b
B^8b
B^7a
BX^9
B^{10}
Paravert. surf.

#40

Plate 1.

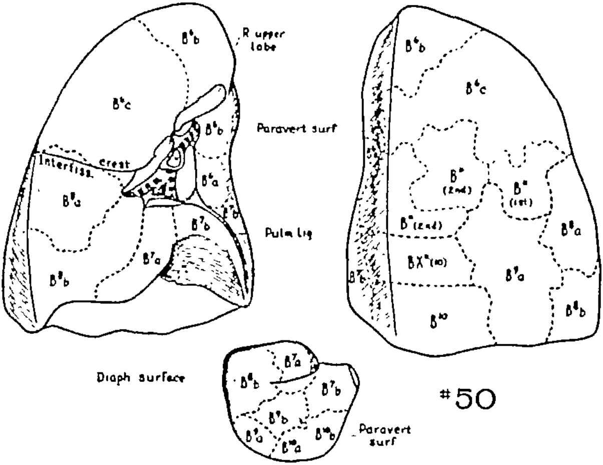

B^6_b
R upper lobe
B^6_c
B^6_a
Interfiss cr
B^8_a
B^*
B^7_b
Pulm lig
B^8_b
B^7_a
B^6_b
B^6_c
B^*
B^8_a
BX^*(mb)
BX^*(ma)
B^*
B^9_a
B^{10}_b
B^{10}_a
B^9_b
B^8_b
Sulcus inf ven cav
B^7_a
B^8_b
B^7_b
B^9_b
B^{10}
Paravert surf

#48

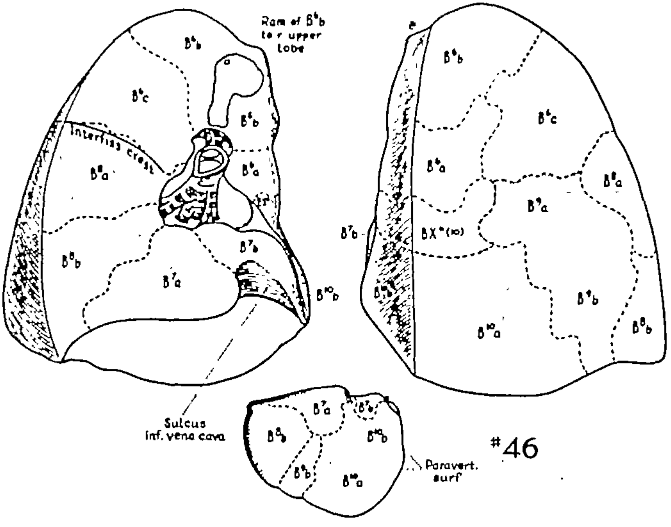

R upper lobe
B^6_c
B^6_b
BX^6_c (from B^6_a)
B^6_b
Interfiss crest
B^6_a
Paravert surf
B^8_a
B^7_a
B^7_a
BX^8_b (from B^9)
Cardiac lobe
B^7_a
BX^8_b
B^7_b
Diaph surface
B^9_b
B^{10}
Paravert surf
Paravert surf
B^6_b
B^6_c
B^6_a
BX^*(10)
B^9_a
B^{10}
B^9_b

#42

Plate 2.


B^6b
R upper lobe
B^6c
Paravert surf
B^6b
Interfiss. crest
B^6a
B^8a
B^7b
B^7b
Pulm lig
B^7a
B^8b
B^6b
B^6c
B^* (2nd)
B^* (1st)
B^* (2nd)
B^8a
$BX^*(10)$
B^9a
B^7b
B^{10}
B^8b
Diaph surface
B^7a
B^8b
B^7b
B^9b
B^9a
$B^{10}a$
$B^{10}b$
Paravert surf

#50


Ram of B^6b to r upper lobe
B^6b
a
B^6c
B^6b
Interfiss crest
B^8a
B^6a
B^8b
B^7b
B^7a
$B^{10}b$
Sulcus Inf. vena cava
a
B^6b
B^6c
B^6a
B^8a
B^9a
B^7b
$BX^*(10)$
B^7b
$B^{10}a$
B^9b
B^8b
B^7a
B^7b
B^8b
$B^{10}b$
B^9b
$B^{10}a$
Paravert. surf

#46

Plate 3.

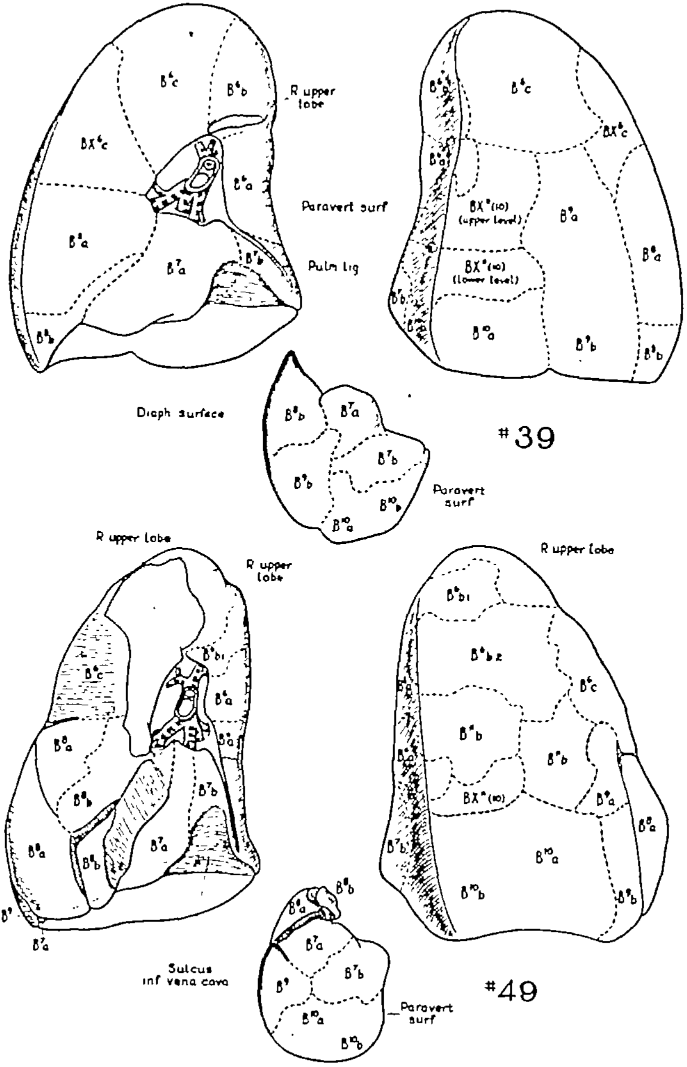

B^{6}c
B^{6}b
R upper lobe
BX^{6}c
B^{6}a
Paravert surf
B^{8}a
B^{7}a
B^{7}b
Pulm lig
B^{8}b
B^{6}b
B^{6}c
BX^{6}c
B^{6}a
BX^9(10) (upper level)
B^{9}a
B^{8}a
BX^9(10) (lower level)
B^{7}b
B^{10}b
B^{10}a
B^{9}b
B^{8}b
Diaph surface
B^{8}b
B^{7}a
B^{7}b
B^{9}b
B^{10}b
B^{10}a
Paravert surf
#39
R upper lobe
R upper lobe
B^{6}b1
B^{6}c
B^{6}a
B^{6}a
B^{8}a
B^{8}b
B^{7}b
B^{8}a
B^{8}b
B^{7}a
B^9
B^{7}a
Sulcus inf vena cava
R upper lobe
B^{6}b1
B^{6}b2
B^{6}c
B^{6}a
B^{9}b
B^{8}b
B^{6}a
BX^9(10)
B^{9}a
B^{8}a
B^{10}a
B^{7}b
B^{10}b
B^{9}b
B^{8}b
B^{8}a
B^{7}a
B^{7}b
B^9
B^{10}a
B^{10}b
Paravert surf
#49

Plate 4.

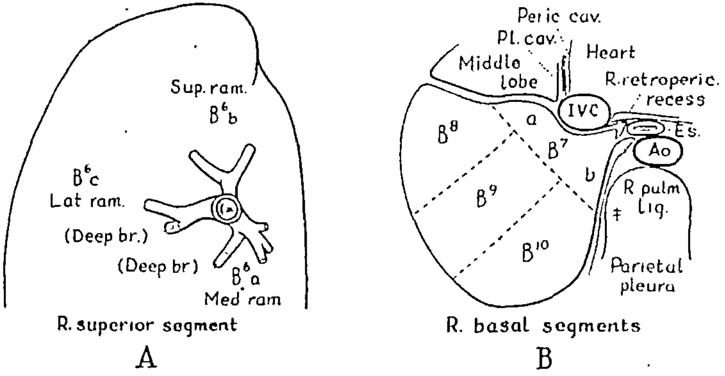


Fig. 2.—*A*, Anterior view of superior segmental bronchus (B^6), showing arrangement of its three rami—B^6a, B^6b, B^6c—in an embalmed specimen (see Fig. 7, *B*). While this represents the common type of bifurcation into B^6a + b and B^6c it is atypical in that it resembles a trifurcation. For more typical mode of branching, see B^6, Fig. 3, *C*.

B, Diagram of transverse section of the right lower lobe through the lower part of the basal segments. Note that the medial basal segment (B^7) is placed athwart the other basal segments (B^8, B^9, B^{10}) and that the latter exhibit a layering, B^8 overlapping B^9, and B^9 overlapping B^{10}. Also note that B^7 lies on both sides of the pulmonary ligament, B^7a typically extending as far as the lateral third of the anterior surface; B^7b reaching well down on the paravertebral surface (‡).

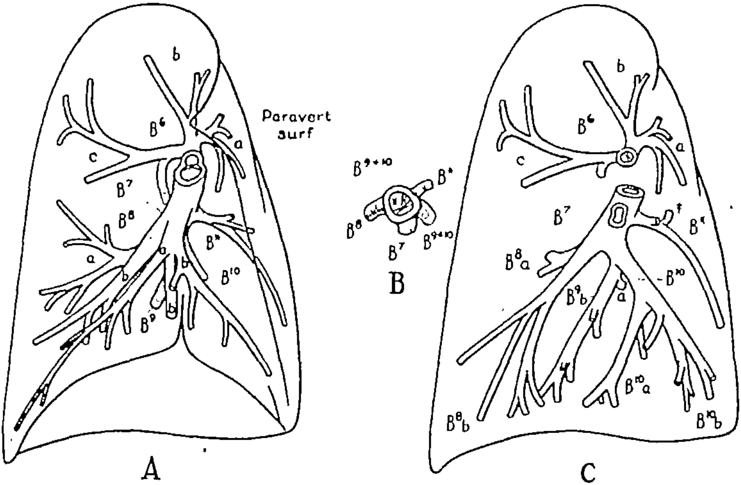


Fig. 3.—Dissection of embalmed right lower lobe as seen from anterior surface.

A, Superficial dissection of bronchi. This specimen is typical in respect to the level of origin of the segmental bronchi B^*, arising from the common stem of B^8, B^9, and B^{10}, but below B^7. It is atypical in that the subsuperior bronchus (B^*) is directed medially instead of posteriorly. For this reason, presumably, the medial ramus of the medial basal (B^7b) does not distribute to the paravertebral surface as it usually does. Correspondingly, the anterior ramus (B^7a) supplies the whole of the lower anterior surface, instead of the usual two-thirds of it. Finally, the deep branch of B^6c takes over part of the posterior distribution of B^*.

B, Orifice of basal stem just below level of B^*.

C, Deeper view of dissection following removal of B^7, the medial basal bronchus. Note deep posterior branch of the subsuperior (‡) that was hidden in *A*. Note absence of BX^* (10)—the high posterior branch of B^{10} which occurs in 86 per cent of specimens. B^6, superior segmental bronchus; B^*, subsuperior bronchus; B^7, medial basal; B^8, anterior basal; B^9; lateral basal; B^{10}, posterior basal segmental bronchus.

not mean that B^6 is typically trifurcate, as implied by Brock (and suggested by the specimen drawn in Fig. 2): for the prevailing pattern (86 per cent) is a bifurcation, B^6c and $B^6a + b$; see Fig. 3 and Plate 2. (See also Table I, item 1.) The remaining items in the table demonstrate how rarely this pattern is modified. In only a few instances (10 per cent), is the segment supplied by an accessory branch of B^8 (see BX^6c, Plate 2, No. 42; Plate 4, No. 39), or by an accessory branch of the subsuperior bronchus, or directly by a branch from the basal stem (see footnotes, Table I).

TABLE I. THE SUPERIOR SEGMENTAL BRONCHUS (B^6)

1. *Bifurcates* into:			94%
1.* $B^6a + b$ and B^6c (Plate 2, No. 42)		86%	
2. Bizarre types		8%	
(1) B^6c2 and $[B^6a + c1 + b]$	2%		
(2) B^6c2 and $[(B^6a + b) + c1]$	2%		
(3)† B^6a and B^6b	2%		
(4)‡ B^6b1 and B^6b2	2%		
II. *Trifurcates* into B^6a, B^6b, B^6c			6%

*In three specimens, part of B^6c arose from the basal stem (No. 17) or from B^8; see No. 42 (Plate 2) and No. 39 (Plate 4).

†B^6c arises as BX^6c from the basal stem.

‡B^6a arises as BX^6a from the subsuperior bronchus (B^*).

B^6c1 arises as BX^6c1 from B^*; B^6c2 from basal stem.

The amount of the lower lobe tissue that is aerated by B^6 is of considerable importance to the clinician since this is frequently involved in lung abscess and frequently separated from the basal segments. For these reasons it has seemed desirable to summarize the limits of the superior segments on all three surfaces of the lower lobe (Fig. 4). Row 1 shows the extent of this segment on the anterior surface, together with the percentages in which it occupies one-third, one-half, or two-thirds or more of the surface. Rows 2 and 3 supply similar data for the costal and paravertebral surfaces, respectively. However, these figures, suggestive as they are, do not in themselves yield the most significant information. This has been obtained by ascertaining the extent of this segment in each specimen and then finding into what groups these specimens can be arranged.

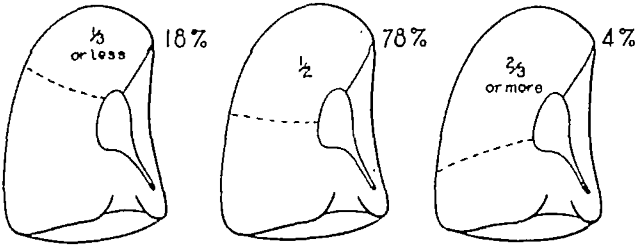
Two major patterns emerge from this analysis. In two-fifths of the specimens (38 per cent) the superior segment is obliquely fitted to the basal segments of the lower lobe. In the remainder (62 per cent), it caps the basal segments horizontally, according to conventional concepts. The whole group may be further subdivided according to whether the segment occupies the upper half

TABLE II. POSITION AND EXTENT OF THE SUPERIOR SEGMENT

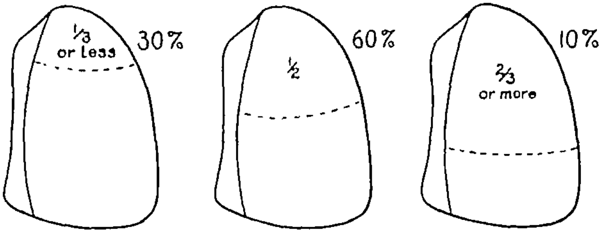
Horizontal group		62%
Upper third	8%	
Upper half	52%	
Upper two-thirds	2%	
Oblique group		38%
Upper third	6%	
Upper half	26%	
Upper two-thirds	6%	

(78 per cent), the upper third (14 per cent), or two-thirds (8 per cent) of the lobe. Details are given in Table II.

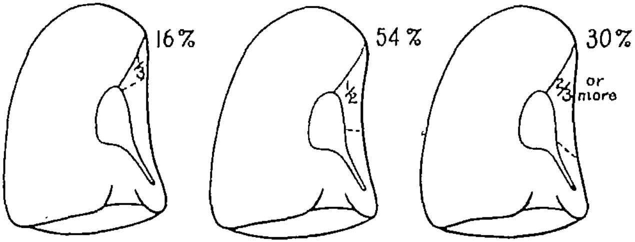
In no instance was the superior segment cut off from the basal segments by a substantial incisure, as described by Dévé (1900) in 6 per cent of 180 infant lungs—the nearest to this condition being shown in Plate 4 (No. 49)—nor was it



Anterior Surface



Costal Surface

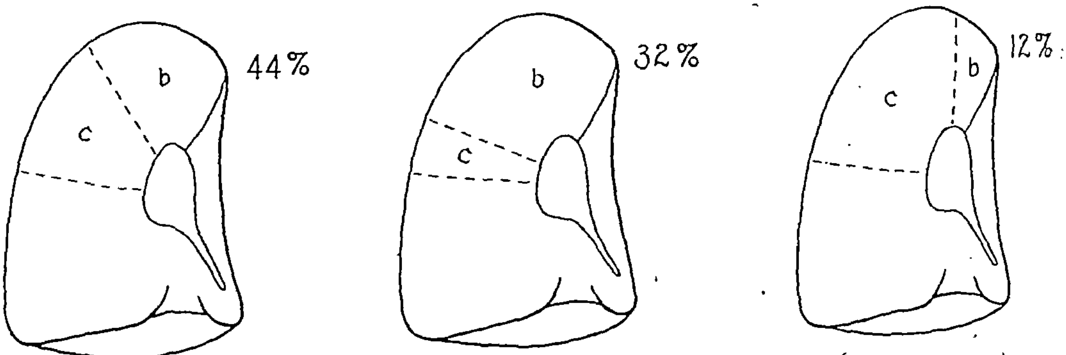


Paravertebral Surface

Fig. 4.—Diagrams illustrating varying extent of the superior segment on anterior, costal, and paravertebral surfaces. Percentages indicate frequency of given distributions.

ever associated with the 36 per cent of incisures demarcating the medial basal segment in our series. Dévé observed a coexistence of these incisures in 11 per cent of infant lungs. (This figure includes incomplete fissures.)

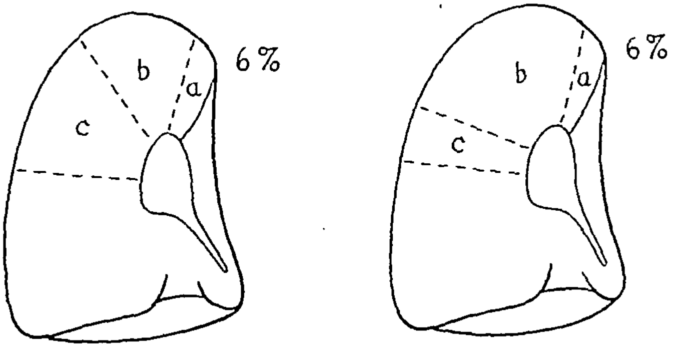
The composition of the anterior and costal surfaces of the segment is displayed in Figs. 5 and 6, respectively. In the prevailing pattern (Fig. 5, 44 per cent), the anterior surface is supplied exclusively and equally by B^6b and B^6c. On the costal surface (Fig. 6), the two most common patterns are those in which rami b and c again divide the area (34 per cent), and those in which rami a, b, and c participate equally (30 per cent). On the paravertebral surface, which has not been plotted because of its constancy, B^6a is present and predominant in 98 per cent of cases. B^6b is the only other ramus which invades this area even to a minor degree and then only in 44 per cent of specimens.



B^6c and B^6b equal
(B^6a absent)

B^6b predominant
(B^6a absent)

B^6c predominant
(B^6a absent)



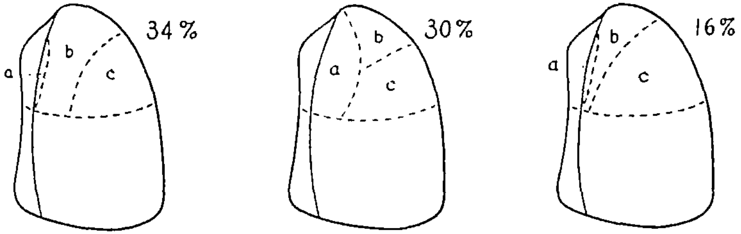
B^6c predominant

B^6b predominant

Fig. 5.—Diagrams illustrating varying extent of anterior surface of the superior segment supplied by individual rami of B^c.

Of the three rami just described, the *medial* (B^6a) is most worthy of attention since this is the one which descends furthest. This agrees with Brock's observation that the downward direction of this branch may be so increased that it runs almost vertically. Thus in 54 per cent of specimens (Fig. 4), it supplies one-half of the paravertebral surface (with or without a small portion of B^6b) and in another 30 per cent it covers two-thirds or more of the surface. Indeed, in two instances it almost reaches the diaphragm (see Fig. 9). From the standpoint of resection of the segment, the importance of this cannot be overemphasized. Another point of interest is that in 38 per cent it develops a deep branch (Fig. 2, *A*) which takes over a substantial portion of the costal surface (see Plate 3, No. 46), but it was never found to predominate on that surface.

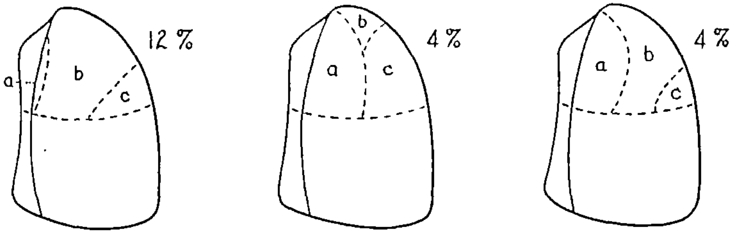
Next in interest is the *lateral ramus* (B^6c). In 84 per cent this has a deep posterior branch (Fig. 3, *A*) and occasionally (16 per cent) it may take over most of the costal surface of the segment (Plates 2 and 4, No. 42 and No. 39). In one instance, what is presumably to be interpreted as this deep branch arose coordinately with the common stem of $B^6a + b$ (see orifice ‡, Plate 1, left side, No. 40). Evidence for this may be found in Plate 3 (No. 50) where the typically placed deep branch of B^6c supplies a comparable zone.



B^6b and B^6c predominant

B^6a, B^6b, B^6c equal

B^6c predominant



B^6b predominant

B^6a and B^6c predominant

B^6a and B^6b predominant

Fig. 6.—Diagrams illustrating varying extent of costal surface of the superior segment supplied by individual rami of B^6.

The *superior ramus* (B^6b) is distributed to both sides of the upper portion of the lobe.

From the standpoint of resection, the common stem of the three rami of B^6 is long enough to permit ligation in 92 per cent of specimens. The same is true of the common stem of $B^6a + b$ in 88 per cent and of the lateral ramus (B^6c) in 100 per cent of specimens.

In concluding discussion of the superior segment attention is again called to the fact that on the right side the upper lobe is usually fused to a greater or lesser degree with the anterior surface of the superior segment where that plane curves to join the paravertebral surface. Usually this area is contiguous to B^6b. In this region (see Plate 3, No. 46), a branch of B^6b was observed to supply the parenchyma of the right upper lobe in five out of eleven consecutive specimens examined for this purpose. A similar situation was noted by Bell (1941). In a personal communication he stated that this fact was observed in a case of lobar pneumonia in which the consolidation extended from the right lower lobe to the adjoining area of the right upper lobe. Post-mortem dissection showed that the bronchial twig from the superior segmental bronchus supplied this area.

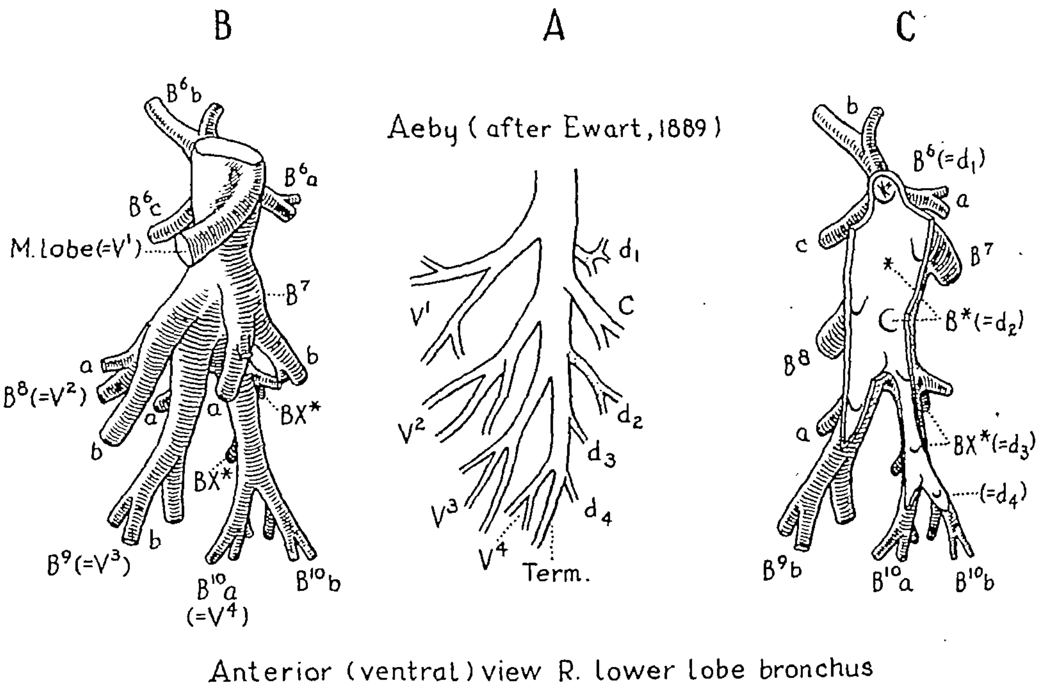


Fig. 7.—Sketches showing the origin and relations of posterior (dorsal) branches of the right lower lobe bronchus.

A, Aeby's diagram illustrating "monopodic" branching of a stem bronchus into a series of ventral (V^{1-4}) and dorsal d_{1-4}) rami. *C*, cardiac bronchus, which does not fall into either of the two series. *Term.*, termination of "stem bronchus."

B, Dissection of embalmed specimen (No. 12, 816), for comparison with Aeby's diagram.

C, Same specimen as in *B*, with anterior wall of bronchial tree removed to show orifices of dorsal rami. In this particular specimen, five instead of Aeby's four dorsal rami occurred. (The first dorsal is represented by B^6.) A sixth is frequently found in certain other specimens at the point indicated by an asterisk, that is on the common stem of $B.^{8,9+10}$ Considering the six in order from above downward. No. 2 and 3 are considered as equivalent to Aeby's d_2. Dorsal bronchi on this part of the stem are here designated the subsuperior proper (B^*), No. 4 and 5 (on the stem of B^{10}) are considered as equivalent to Aeby's d_3 and are here designated as the accessory subsuperior, BX^* (10). Bronchi arising in positions 2 to 5 usually supply the subsuperior segment, and not successively lower zones, as might be inferred from their position on the stem bronchus.

THE SUBSUPERIOR BRONCHUS (B^*)

The subsuperior bronchus, as indicated by its name, arises beneath the superior bronchus (B^6) either from the posterior portion of the basal trunk (B^*, Fig. 7, *C*) or from the upper portion of the posterior basal bronchus (BX^*, Fig. 7, *C*). It is distributed to the middle level of the posterior costal surface of the lobe. It may extend onto the paravertebral or onto the lateral costal surface. This is one of the zones which has been considered to be most vulnerable to aspirated material (Neil, Gilmour, and Gwynne, 1937).†

The first to recognize a series of dorsal or posterior branches on the stem bronchus of man was the Swiss comparative anatomist, Aeby (1880). He postulated a monopodic branching consisting of four ventral and four dorsal rami. In this he was guided by the prevailing mammalian pattern in which the thorax is long and narrow and the heart placed near the middle of the thorax. Such a scheme is shown at *A* in Fig. 7. Ewart (1889), however, took exception to this *rationalization*, stating that due to the different shape of the human thorax, which is compressed from front to back, with the heart placed inferiorly, the branching of the human bronchial tree is of necessity more radial, and more dichotomous, than monopodic (see *B*, Fig. 7). Furthermore it has been our experience that the four dorsal branches postulated by Aeby do not occur regularly in the right lower lobe bronchus of man, and that potentially there are six sites, as shown at *C* in Fig. 7: (1) the site of the first dorsal branch of Aeby (d_1), which is the superior segmental bronchus (B^6); (2) the dorsal branch between B^7 and B^8 (marked by an asterisk in *C*, Fig. 7); (3) the dorsal branch between B^8 and $B^{9,10}$ (Aeby's d_2); (4) the dorsal branch at the upper end of B^{10}; (5) the dorsal branch at the middle of B^{10} (Aeby's d_3); and (6) the dorsal branch of $B^{10}b$ (Aeby's d_4). However, for the sake of simplification, dorsal branches 2 and 3 are here grouped together and considered as corresponding to Aeby's d_2, and dorsal branches 4 and 5 as corresponding to Aeby's d_3. It is thus convenient to refer to the subsuperior bronchus as arising either at level d_2 or level d_3, that is, from some portion of the main stem or from B^{10}, respectively. The first will be referred to as the *subsuperior proper*, with the designation B^* (after Boyden, 1945) and the second as the *accessory subsuperior*, with the designation BX^*.

In considering that both B^* and BX^* represent a subsuperior (in which view Brock also concurs) we have been guided by the fact that in the absence of a B^* the BX^* distributes to the subsuperior zone rather than to a distinctly lower level, a fact which again may be referred to the radial type of branching of the human lung.

Somewhat similar to Fig. 7, *C* is a sketch presented by Neil, Gilmour, and Gwynne (1939), showing the opened bronchial tree of a 4-year-old child in which three subsuperiors are present (their Fig. B). The first two correspond to the d_2 level, and the third—if the specimen had had the usual high bifurcation of B^{9+10}—to the d_3 level, as postulated in Fig. 7, *C*. In general, these authors stated that there are one to three present, and this corresponds to our observations; for inspection of Table III (Item I) will show that one or more subsuperiors are present in every specimen. In 50 per cent only one occurs (Item II:1); in 34 per cent two are present (Item II:2); in 14 per cent three occur (Item II:3), and in one specimen even four such dorsal rami were noted (Item II:4).†

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†At first unaware of Ewart's earlier identification of it (as the "lesser posterior horizontal") they claimed discovery of a new segment—naming it the "subapical"; and, indeed, it had been overlooked by Kramer and Glass (1932). Neil's excellent description of it, with emphasis on its clinical importance is as follows:

> "The posterior region of the lower lobe is supplied, according to all previous publications to which we have had access, by the apical bronchus [B^6] in the upper portion and the paravertebral [B^{10}] in the lower. We are convinced that an intermediate separate segment exists and can be demonstrated, and that it is the site of localized pathological change, as shown by radiology and bronchoscopy. It is an anatomical gap in the distribution between the apical and paravertebral bronchi in all illustrations we have seen. We have found that it is supplied by these subapical bronchi [B^* and BX^*]. This has been shown by inflation in specimens and by lipiodol fillings in patients."

TABLE III. SUBSUPERIOR BRONCHI (B^* AND BX^*)

I. Frequency of occurrence in 50 specimens			
1. Arises exclusively from level d_2 (as branch of main lower lobe bronchus between the superior and the basal segmental bronchi)			14%
2. Arises exclusively from level d_3 as an accessory subsuperior, $BX^*(10)$, i.e., one or more from the posterior basal bronchus (B^{10})			38%
3. Arises from both levels in same specimen			48%
			100%
II. Detailed analysis			
1. Subsuperior represented by single bronchus			50%
(1) Arising at d_2 level (as B^* proper)		14%	
(a) From common stem of $B^{8,9,10}$	6%		
(b) From common stem of $B^{9,10}$	8%		
(2) Arising at d_3 level, as $BX^*(10)$		36%	
2. Subsuperior represented by two bronchi			34%
(1) One from level d_2 (B^*), and one from level d_3, as $BX^*(10)$		32%	
(2) Two from level d_3, as $BX^*(10)$		2%	
3. Subsuperior represented by three bronchi			14%
(1) Two from level d_2 (B^*) and one from level d_3, as $BX^*(10)$		10%	
(2) Two from level d_3, as $BX^*(10)$ and one from level d_2, as B^*		4%	
4. Subsuperior represented by four bronchi (Two from each level)			2%
			100%
III. Origin of B^* (at d_2 level). (Items I:1 and I:3)			62%
1. From basal stem (level of B^7)		12%	
2. From common trunk of $B^{8,9,10}$		22%	
3. From common trunk of $B^{9,10}$		14%	
4. Two: one from common trunk of $B^{8,9,10}$ and one from $B^{9,10}$		6%	
5. Two from common trunk of $B^{9,10}$		8%	

At this point one may ask why Neil, Gilmour, and Gwynne have not been followed in giving the subsuperior the status of a segmental bronchus. The answer lies in their observations and ours, namely, that the number and level of origin of bronchi supplying this middle posterior zone are variable, hence it is less confusing to give it a designation (B^*) that is noncommittal as to numerical sequence.

Another point made by Neil and his co-workers is that they have observed the subsuperior (subapical) "arising from the dorsal, mesial, or lateral aspect of the right main bronchus." Similarly, we have found that occasionally B^* inclines to the medial or lateral side. In the former position it may give rise to the medial ramus of the medial basal bronchus (B^7b)‡; but in general

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†It should be pointed out that the precise level of branching of the bronchi can be determined only by opening the stem bronchus. That is, one cannot always tell from the external view whether a dorsal ramus is originating from the upper part of B^{10} or the lower portion of B^{9+10}. This emphasizes the necessity of preoperative bronchoscopy or bronchography.

‡In Fig. 3A, B^* is medial and is taking over part of the territory of B^7, but has not replaced it.

Brock's description applies to the usual arrangement, namely that "typically [the subapical] arises from the posterior wall of the lower lobe bronchus—as it were, in series with [the apical bronchus]—. When it does not arise from the lower lobe stem it may originate from the posterior basal bronchus—still roughly parallel to [the apical bronchus]." Using Brock's definition, however, we have found the subsuperior occurring in 100 per cent of our smaller series of dissected specimens, in contrast to the 48 per cent incidence in his larger series of 170 bronchograms.

Hitherto the subsuperior has been discussed from the standpoint of its origin on the bronchial tree. Equally important is its distribution on the surface. Turning first to the subsuperior proper (B^*), analysis of the fifty injected specimens shows that in all but one of the thirty-one specimens in which it occurs (Table IV), it aerates at least the posterior sector of the right lower lobe. In 36 per cent it distributes to at least the posterior and the adjacent paravertebral area, and in 32 per cent it aerates at the least the posterior and the adjacent posterolateral area. It would seem, therefore, that to be a subsuperior proper this bronchus must supply at least the posterior sector but that it may spread either medially (B^*, Plate 2, No. 48) or laterally (B^*, Plate 1, No. 43) or in both directions (B^*, Plate 4, No. 49).

For percentages of types see Table IV.

TABLE IV. DISTRIBUTION OF THE SUBSUPERIOR (B^*)

AREA	PER CENT
Posterior and adjacent paravertebral	20
Posterior and adjacent posterolateral	16
Posterior, paravertebral, and posterolateral	16
Posterior alone	8
Posterolateral alone	2

When the subsuperior proper is absent, its zone is usually supplied by a dorsal ramus arising from the posterior basal bronchus (B^{10})—level d_2 of Aeby. This is the ramus we have called the accessory subsuperior, BX^* (10). It, too, almost always supplies at least the posterior sector (Plate 2, No. 42) but may spread medially to the paravertebral area (Plate 3, No. 46) or laterally to the posterolateral zone; or it may be displaced medially or laterally (Plate 1, No. 40) by one of the deep branches of B^*. For percentage of types, see Table V.

TABLE V. DISTRIBUTION OF THE ACCESSORY SUBSUPERIOR (BX^*) IN THE ABSENCE OF A SUBSUPERIOR (B^*)

AREA	PER CENT
Posterior alone	28
Posterior and adjacent paravertebral	4
Posterior and adjacent posterolateral	4
Posterolateral alone	2
Total	38

When both the subsuperior proper and the accessory subsuperior are present (48 per cent), the latter either distributes to the area beneath the former (BX^*, Fig. 9) or shifts medially, or to the lateral side of it (BX^*, Plate 2, No. 48), or telescopes it (Fig. 8). In only one-sixth of these specimens does BX^*(10)

supply so low a zone as to be considered part of the posterior basal rather than the subsuperior segment (namely, No. 50, Plate 3).†

When there are two accessory subsuperiors (8 per cent), one may lie below the other, in the posterior sector, or they may lie side by side (BX*, Plate 2, No. 48). If the lower one distributes too inferiorly it may be considered a part of the posterior basal segment (namely, No. 39, Plate 4).†

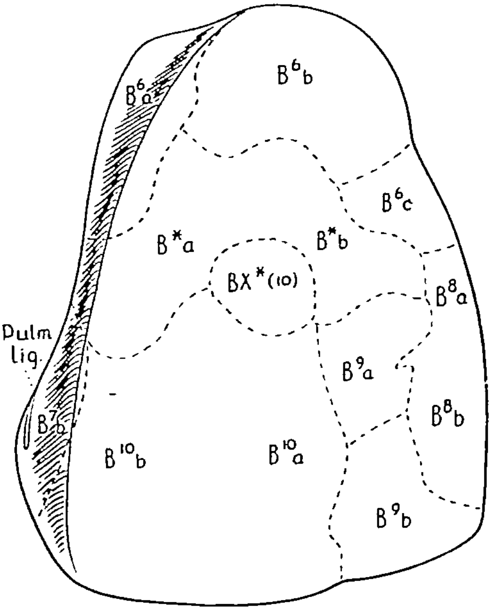

Fig. 8.

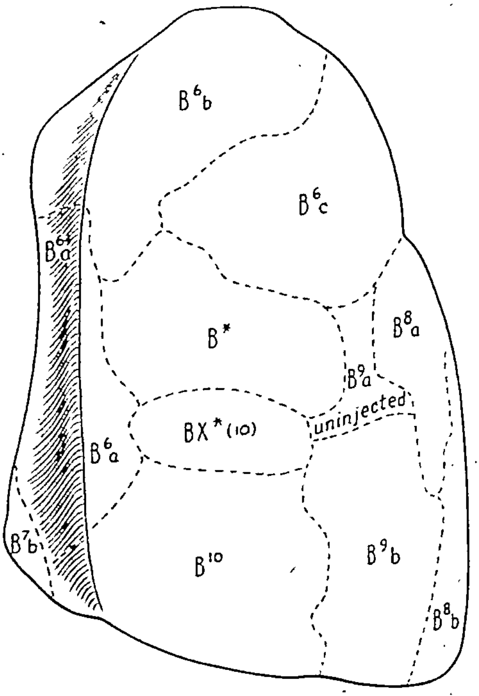

Fig. 9.

Figs. 8 and 9.—The costal surface of two injected specimens showing varying distributions of the subsuperior proper (B*) and of the accessory subsuperior bronchus (BX*). In each specimen B* arises at a level between B^7 and B^8, and BX* several centimeters below this from B^{10}, but in No. 16, BX* telescopes the zone supplied by B*, while in No. 38, it lies inferior to it. These specimens belong to that 48 per cent of lungs in which the subsuperior proper and the accessory subsuperior are present in the same lobe.

Specimen No. 38 also illustrates the fact that B^6a, the medial ramus of the superior segment, may take over almost the whole of the paravertebral area. In other words the superior segment may extend nearly to the diaphragmatic surface.

Of special interest are the 12 per cent of specimens in which two subsuperiors are present in addition to one, or even two, accessory subsuperiors (Table III, Item II:3[1] and II:4). In the former type, one B* may arise above the other but they distribute to zones lying side by side, as B* (first) and B* (second) in Plate 3, No. 50. Thus, they simulate the zone supplied by the two branches of a single subsuperior (B,* a and* b, Plate 1, No. 43; see also Fig. 1,*A*).

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†In such specimens the bronchi which by origin were destined to be accessory subsuperiors have been deflected downward by other bronchi. In these few specimens one thus encounters a transitional pattern of Nature which confounds man-made classifications. We have chosen to meet the dilemma by retaining the number BX*, to indicate that the bronchus has the same origin as that which supplies the subsuperior zone, but giving the zone the color of the posterior basal segment (see Plate 3, No. 50).

THE BASAL BRONCHI (B^{7-10})

The basal bronchi are four in number and arise from the basal trunk—that portion of the lower lobe bronchus which is distal to the superior segmental bronchus (B^6). As seen in cross section (Fig. 1,*B*), the major branches of the basal stem are seen to radiate in different directions. The *medial basal* (B^7), the highest branch, arises anteriorly (Fig. 3,*A*) and is distributed to the anterior and paravertebral surfaces (Fig. 1). The next branch, the *anterior basal* (B^8), arises anterolaterally (Fig. 3,*C*) and distributes to the anterior surface and lateral costal area. The next two segmental bronchi arise from a common stem which passes downward in a somewhat posteromedial direction (Fig. 3,*C*). The *posterior basal* (B^{10}) continues the direction of the common stem and distributes to the paravertebral surface and posterior costal surface. The *lateral basal* (B^9) diverges in a posterolateral direction, supplying the posterolateral sector of the costal surface. For this reason it appears to be a lateral branch (V_2) of the stem bronchus of Aeby (Fig. 7,*A*). It is useful to think of it this way provided one does not accept all the implications of the Aeby theory.

Another useful concept is the one advanced by the Russian surgeon Melnikoff (1922)—namely, that in dissecting the lung the lower lobes seem to separate into a series of oblique overlapping layers. We would restrict this to the last three basal zones (B^8, B^9, B^{10}) and add that B^7 is applied at right angles to these (Fig. 2,*B*; compare also with overlapping bronchi in Fig. 7,*B*).

1. *The Medial Basal Segmental Bronchus* (*B^7*).—The medial basal segmental represents the cardiac or infracardiac bronchus of mammals, which in most species occupies the space between the heart and the diaphragm. Its position on the stem is also characteristic, it being the only basal bronchus which constantly arises anteromedially (see Fig. 7). Because of this position one would anticipate that it would distribute to both the anterior and the paravertebral surfaces. Such is the case in 78 per cent of the 50 specimens examined.† Typically, it divides into an anterior (B^7a) and a medial ramus (B^7b), the line between the two falling, usually, in the sulcus of the inferior vena cava (Plate 4, No. 39).

In 14 per cent, B^7 was found to be absent as such—that is, no bronchus having that origin was distributed to that territory. In such specimens the anterior and paravertebral components of the zone were aerated by two displaced bronchi, one being an accessory branch of the anterior basal (BX^7a from B^8b) and the other an accessory branch of the subsuperior (BX^7b from B^*). In the remaining specimens (8 per cent), B^7 supplied only the anterior surface but these were peculiar in that while B^7 arose normally in one specimen (namely, Plate 3, No. 46), both of its rami were distributed to the anterior surface exclusively (see also Fig. 3,*A*). In the other three, only the anterior ramus arose in the usual position, the medial ramus originating as an accessory bronchus of the subsuperior (B^*) or of the posterior basal (B^{10}).‡

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†These observations are thus in accordance with the recent figures of Lucien and Beau (Mattei, 1946) but at variance with Jackson and Huber's account of the extent of this segment. Their figures show no distribution of the medial basal bronchus on the paravertebral surface.

‡It is interesting to note that Huntington (1920) used the cardiac bronchus of mammals as an example of the method of formation of accessory bronchi. He said, "It happens occasionally that a peripheral lung segment receives its bronchial supply from two sources. The terminal alveoli of each contributing bronchus are closed off within the segment of the district which it supplies and do not communicate with those of its colleague. Together the two components make up a topographical pulmonary district ordinarily served by a single bronchus."

TABLE VI. MEDIAL BASAL SEGMENTAL BRONCHUS (B^7)

I. B^7 present on both sides of the pulmonary ligament			78%
1. Distributes to more than one-half of the lower anterior surface		54%	
2. Distributes to one-half or less than one-half of the lower anterior surface		24%†	
II. B^7 wholly anterior			8%
1. Both rami present (No. 46, Plate 3; Fig. 3)		2%	
2. B^7 present but one ramus displaced		6%	
(1) Medial ramus (BX^7b) from B^*	4%		
(2) Medial ramus (BX^7b) from B^{10}	2%		
III. B^7 absent as such			14%
BX^7a from B^8		14%	
BX^7b from B^*	12%		
from B^{10}	2%		

†In one specimen (No. 43, plate 1) B^7 consisted only of a medial ramus (B^7b). BX^7a arose from B^8.

The extent of the anterior surface supplied by B^7, as measured along the diaphragmatic margin, is variable. According to Brock, "it commonly occupies less than a half of the anterior margin," but as may be seen in Table VI (Item I:1) it occupies more than one-half of the anterior surface in two-thirds of the typical specimens. If all are included that have a B^7 of typical origin (86 per cent), B^7 occupies two-thirds or more of the anterior surface in 50 per cent of specimens, one-half in 28 per cent, and only one-third or less in 8 per cent.

Its paravertebral extent is also variable, ranging from an area exceeding one-half of the vertical extent of that surface (Plate 1, No. 40) to a small zone at the extreme lower end of the lobe (Plate 2, No. 48). In only one instance did it invade the costal surface (Plate 1, No. 43). When it fails to occupy the paravertebral area or supplies only a minimal portion of it, the remainder of its territory is taken over by adjacent bronchi—B^6a (Fig. 9), or B^* (Plate 2, No. 48), or a medial branch of B^{10} (Plate 3, No. 46), or any combination of these.

Of special interest are the cases in which B^7 is absent (Item III, Table VI), or wholly anterior (Item II), with the medial ramus (B^7b) developing as an accessory branch of the subsuperior. In such instances the subsuperior arises from a posteromedial position (see B^*, Fig. 3, *A*), at the same level on the tree as B^7. In this position it could well be mistaken for the latter, and apparently that is the interpretation given by Nelson in Fig. 2 of his 1934 article. This led him to minimize the importance of the medial basal segment: "On the right side there is a separate cardiac branch arising from the medial wall of the lower lobe bronchus; it runs downward and slightly inwards and backwards, to supply a small area just below the root of the lung. On account of its small size, this bronchus will not be considered again."

Dévé (1900) noted an incisure on the diaphragmatic surface in 35 per cent of 180 lungs. From its position he judged that this incisure demarcated a zone corresponding to the cardiac lobe of mammals. A similar incisure of varying depth was observed in 38 per cent of the 50 specimens injected in this laboratory. In all but 2 per cent, the incisure marked the lateral boundary of the medial basal segment. Two-thirds of these were pronounced and some would have been demonstrable roentgenologically. All of them would have been noted upon surgical exploration.

In this connection, a word must be said about the relation of the pulmonary ligament to the medial basal segment. Both Dévé's Fig. 6 and Brock's Fig. 94 portray the pulmonary ligament as reflected from the lung at the posterior boundary of B^7 (see ‡, Fig. 2, *B*). In the large majority of specimens, however, the pulmonary ligament is reflected from the lung just upon or just posterior to what these authors call the "horn-like projection of the cardiac segment." In other words the right "retro-pericardiac recess" is shallow, necessitating severance of the pulmonary ligament in an interlobar approach for resection of the medial basal segment.

Because of the fissures just noted, and the superficial position of the segment, and the accessible (high) origin of the bronchus, it is felt that this zone constitutes a surgical unit which may be readily resected. Indeed, there is at least one published instance (Scannell) in which this has been successfully accomplished, for removal of a bronchiectatic segment.

2. *The Anterior Basal Segmental Bronchus* (B^8).—The anterior basal segmental bronchus is the second of the basal bronchi and arises a little below B^7 from the anterolateral aspect of the basal trunk (Figs. 3, *B* and 7). It is remarkably constant in its distribution, dividing into lateral (B^8a) and basal (B^8b) rami.

The former supplies the lower middle-anterior and lateral costal surfaces of the lobe (Plate 3, No. 46). In only 4 per cent of the fifty specimens could it be traced to the diaphragm. The upper limit of its distribution coincides with the *interfissural crest*, a more or less inconspicuous ridge on the lower lobe marking the junction of the upper and middle lobes. In 4 per cent of specimens it gives off an accessory branch (BX^8c) which extends above the interfissural crest to invade the territory of the superior segment (Plate 2, No. 42; Plate 4, No. 39).

The basal ramus (B^8b) distributes to the lower anterior (interlobar) and lower lateral costal surfaces of the lobe in addition to the anterolateral diaphragmatic surface (Plate 2, No. 48). Its extent on the interlobar surface is variable. Usually, it occupies only the lateral third (50 per cent of specimens), as measured along the inferior margin. In 16 per cent it extends medially into the sulcus of the inferior vena cava by virtue of an accessory ramus, BX^7a (Plate 1, No. 43). In one instance B^8b was displaced, occurring as an accessory ramus of B^9 (Plate 2, No. 42). In still another specimen the anterior segment occurred as a bifid lobe (Plate 4, No. 49). This was the only example of an incisure between B^8 and B^9.

In three of the four specimens in which B^9 was absent, B^8b spreads more posteriorly; in the fourth it has an accessory bronchus (BX^9b; Plate 1, No. 40).

In concluding this section, we believe that the anterior basal segment, like the medial basal, is readily resectable; for its bronchus has a high anterior origin, its distribution is fairly constant, and its medial border is frequently marked by an incisure (36 per cent of specimens).

3. *The Lateral Basal Segmental Bronchus* (B^9).—The lateral basal segmental bronchus usually arises from the anterolateral aspect of the short common stem of B^9 and ^{10} (Fig. 7, *B*). In only 10 per cent of specimens was this a long com-

mon stem. In another 8 per cent, B^9 was entirely absent as such. We agree with Brock that it is smaller than the anterior basal (B^8) and appears much more like a secondary branch of the posterior basal (B^{10}) than an important independent branch. It is distributed to the posterolateral sector of the basal half of the lower lobe (Plate 2, No. 48).

Almost immediately after its origin the bronchus divides into lateral (B^9a) and basal (B^9b) rami. The lateral branch, when present (86 per cent), is quite constant both in origin and in distribution, supplying in 74 per cent of specimens the posterolateral area adjacent either to the subsuperior bronchus (Plate 4, No. 49) or to the displaced subsuperior bronchus (Plate 3, No. 46). In a fifth of this 74 per cent, the lateral ramus even encroaches upon the subsuperior zone (see Plate 3) and might be considered to contribute to that interpolated segment. An example of its infrequent lower position may be seen in Plate 2 (No. 48) and Plate 3 (No. 50). The latter is the only case in which it extended to the diaphragm. In the 14 per cent of specimens in which it is absent its place is taken by a subsuperior (10 per cent; Plate 1, No. 40) or by the lateral ramus (B^8a) of the anterior basal (4 per cent).

The basal branch (B^9b) supplies the inferior posterolateral costal area and the corresponding sector of the diaphragmatic surface (Plate 4, No. 39). In the 8 per cent of specimens in which it was absent its place was taken by B^8b—by spread of that ramus in three instances, and by an accessory branch of that ramus (BX^9b) in one instance (Plate 1, No. 40).

4. *The Posterior Basal Segmental Bronchus (B^{10}).*—The posterior basal segmental bronchus appears to be the continuation of the right lower lobe bronchus, particularly the branch here designated as $B^{10}b$ (Figs. 3 and 7) which extends to the inferior posteromedial corner of the lobe. In dissecting specimens it has been found most useful to locate this ramus first, then the other branches may be quickly identified.

Typically B^{10} breaks up into three major branches. The highest (formerly numbered $B^{10}a$, Boyden 1945) has already been demonstrated to be in reality a displaced subsuperior, and accordingly has been redesignated BX^*(10). It will be recalled that this is a fairly constant branch occurring in 86 per cent of specimens (see Table III).

Having disposed of this high dorsal branch (from Aeby's level 3), let us now consider the two major branches of the posterior basal, herewith designated the laterobasal ($B^{10}a$) and mediobasal ramus ($B^{10}b$).† In over one-half the specimens (58 per cent), $B^{10}b$ arises somewhat behind $B^{10}a$, but in virtually all cases both rami are distributed to both the costal and diaphragmatic surfaces. In addition, $B^{10}b$ is distributed to the paravertebral surface (for example, Plate 4, No. 49). Occasionally (10 per cent), a particular paravertebral branch of B^{10} may be noted, but it is not constant enough to merit a name.

SUMMARY

The distribution and arrangement of the segmental bronchi of the right lower lobe have been studied in fifty fresh lungs by the following methods: (1) the successive injection of the principal bronchi by differently colored gelatin masses; (2) the accurate sketching of each injected lobe, to record the surface distribution of the bronchi on interlobar, costal, and diaphragmatic surfaces; (3) the dissection of each lobe, to verify the distribution of bronchi, and to ascertain their mode of branching.

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†These are the rami formerly designated by Boyden (1945) as $B^{10}b$ and $B^{10}c$.

From these data it has been possible to establish the prevailing pattern empirically, and to analyze the principal variations in the light of that knowledge.

As viewed from the interlobar surface the right lower lobe may be divided into superior and basal zones, the line of separation usually falling at the interfissural crest. Posteriorly, an interpolated, "subsuperior" zone can be demonstrated between superior and basal segments in 100 per cent of specimens (vide infra).

The Superior Segment.—Since the superior segment is resectable, it is important to know its extent. Prevailingly, it "caps" the basal segments horizontally, but in 38 per cent of specimens it is obliquely fitted to the basal segments. Usually (in 78 per cent), it occupies the upper half of the lobe, but it may occupy two-thirds of the lobe (8 per cent) or only one-third (14 per cent). On the paravertebral surface it may extend two-thirds (or more) of the way to the diaphragm (30 per cent of specimens).

The superior segmental bronchus (B^6) has three constant rami—a medial (B^6a), a superior (B^6b), and a lateral ramus (B^6c)—but it rarely trifurcates (6 per cent), the prevailing pattern (86 per cent) being a bifurcation into $B^6a + b$ and B^6c. On the interlobar surface the superior segment is usually fused to a greater or lesser degree with the right upper lobe; and in five out of eleven consecutive specimens examined for this purpose a branch of B^6b was observed to supply the adjacent portion of the right upper lobe. This may explain how consolidation of the lower lobe, in lobar pneumonia, may extend into the adjoining area of the upper lobe.

The *subsuperior* zone is a constant posterior zone interpolated between superior and basal segments. In this series of dissections it has been identified in 100 per cent of specimens, as contrasted with Brock's identification of only 48 per cent in a series of bronchograms. It is supplied by one or more posterior bronchi of inconstant origin. These arise from levels 1.5 to 5 cm. below the orifice of the superior bronchus (B^6). For this reason, the bronchi supplying this zone have been indicated by the noncommittal designation, "B^*" (Boyden, 1945).

In general the principal levels of origin correspond to Aeby's dorsal bronchi, d_2 and d_3 (the first dorsal being the superior bronchus, B^6). That posterior bronchus which arises from Level 2 (that is, from the common stem of $B^{8,\ 9,\ \text{and}\ 10}$ or B^{9+10}) is designated the "subsuperior proper," B^*. That posterior bronchus which arises from Level 3 (that is, from the trunk of B^{10}) is designated the "accessory subsuperior," $BX^*(10)$.

In about one-half the specimens (48 per cent), the subsuperior bronchi arise from both levels, and range in number from two to four. In the remaining one-half (52 per cent), there is only one subsuperior bronchus—more commonly BX^* (38 per cent), as against 14 per cent with a subsuperior proper.

Primarily the subsuperior zone lies in the posterior sector of the lobe, but it may spread laterally or medially. It is a common site of lung abscess.

The *basal bronchi* are four in number and tend to radiate from above downward into the anteromedial, anterolateral, posterolateral, and posteromedial sectors of the lobe, respectively.

The *medial-basal segmental bronchus* (B^7) is the highest in origin. It distributes to the zone that lies on either side of the pulmonary ligament (78 per cent of specimens), and is placed athwart the other basal zones—that is, it occupies a plane virtually at right angles to the others. This segment corresponds to the cardiac lobe of mammals. Therefore, it is not surprising to find an incisure of varying depth separating it from the anterior-basal segment in 36 per cent of specimens. In two-thirds of this number the incisure is possibly deep enough to have been visible in a roentgenogram.

The bronchus to this "cardiac" region commonly divides into an anterior (B^7a) and a medial ramus (B^7b). The line between the two usually falls in the sulcus of the inferior vena cava.

In 14 per cent of specimens the medial basal bronchus is absent as such, the zone being supplied by one or two accessory rami from the adjacent bronchi—B^8, B^*, or B^{10}.

Contrary to Brock, the zone prevailingly occupies two-thirds or more of the anterior margin of the lobe; and contrary to Jackson and Huber it usually extends onto the paravertebral surface.

Because of the high accessible origin of its bronchus, the frequent presence of incisures and the superficial position of this segment, it is deemed suitable for resection.

The *anterior basal segmental bronchus* (B^8) is remarkably constant. It arises from the anterolateral aspect of the basal trunk, a little below B^7. It soon divides into a lateral (B^8a) and a basal ramus (B^8b). The former supplies the area on either side of the interlobar margin below the level of the interfissural crest. The latter supplies the lower part of this sector including the corresponding diaphragmatic area. Usually (50 per cent), B^8b occupies only the lateral one-third of the lower interlobar surface as measured along the inferior margin of the lobe, but in 16 per cent of specimens it extends as far medially as the sulcus of the inferior vena cava. In another 8 per cent it takes over the territory of B^9b. Occasionally (4 per cent), the lateral ramus (B^8a) invades the superior segment.

Because of the high origin of B^8, its fairly constant distribution, and the fact that its medial border is frequently marked by an incisure (36 per cent) it, too, is deemed suitable for resection.

The *lateral basal segmental bronchus* (B^9) arises deep within the lobe and is not considered to be readily resectable. It is absent in 8 per cent of specimens. Typically it divides almost immediately after its origin into a lateral (B^9a) and a basal bronchus (B^9b). The former ramus, when present (86 per cent), supplies the posterior lateral zone adjacent to the subsuperior. When absent, its territory is supplied by B^{*} or $B^{8}a$. The basal ramus ($B^{9}b$) supplies the lower posterior lateral sector and the corresponding diaphragmatic area. When absent (8 per cent), its territory is taken over by $B^{8}b$.

The *posterior basal segmental bronchus* (B^{10}) appears to be a continuation of the lower lobe bronchus—particularly the ramus $B^{10}b$ which extends into the inferior, posteromedial corner of the lobe. Typically, B^{10} breaks up into three major branches. The highest is that which has been already described as the accessory subsuperior, $BX^{*}(10)$. It occurs in 86 per cent of specimens and is reflected upward or backward to supply the subsuperior segment. The two remaining major branches (the mediobasal, $B^{10}b$, and the laterobasal ramus $B^{10}a$) pass respectively to the paravertebral and posterior surfaces, and to the corresponding diaphragmatic sectors.

Because of the inaccessibility of its origin, this bronchus, like B^{9}, is not considered to be readily resectable.

REFERENCES

Aeby, Ch.: Der Bronchialbaum der Säugethiere und des Menschen, nebst Bemerkungen über den Bronchialbaum der Vögel und Reptilien, Leipzig, 1880.

Bell, E. T.: A Text Book of Pathology, ed. 4, Philadelphia, 1941, Lea & Febiger, p. 646.

Boyden, E. A.: The Intrahilar and Related Segmental Anatomy of the Lung, Surgery 18: 706-731, 1945.

Boyden, E. A., and Hartmann, J. F.: An Analysis of Variations in the Bronchopulmonary Segments of the Left Upper Lobes of Fifty Lungs, Am. J. Anat. 79: 321-360, 1946.

Boyden, E. A., and Scannell, J. G.: An Analysis of Variations in the Bronchovascular Pattern of the Right Upper Lobe of Fifty Lungs, Am. J. Anat. 82: 27-74, 1948.

Braus, Hermann: Anatomie des Menschen, Bd. 2, Eingeweide, Berlin, 1924, Julius Springer, 607 pp. (Fig. 100).

Brock, R. C.: The Level of the Interlobar Fissures of the Lung, Guy's Hosp. Rep. 91: 140-146, 1942.

Brock, R. C.: Observations on the Anatomy of the Bronchial Tree, With Special Reference to the Surgery of Lung Abscess; Part IV. The Lower Lobes, Guy's Hosp. Rep. 92: 123-144, 1943.

Brock, R. C.: The Anatomy of the Bronchial Tree With Special Reference to the Surgery of Lung Abscess, London, 1946, Oxford University Press, 96 pp.

Dévé, F.: Les lobes surnuméraires du poumon, Bull. et mém. Soc. anat. 75: 341-367, 1900.

Ewart, William: The Bronchi and Pulmonary Blood Vessels—Their Anatomy and Nomenclature; With a Criticism of Professor Aeby's Views on the Bronchial Tree of Mammalia and of Man, London, 1889, J. & A. Churchill, Ltd., 232 pp.

Huntington, G. S.: A Critique of the Theories of Pulmonary Evolution in Mammals, Am. J. Anat. 27: 99-201, 1920.

Jackson, C. L., Jr., and Huber, J. F.: Correlated Applied Anatomy of the Bronchial Tree and Lungs With a System of Nomenclature, Dis. of Chest 9: 1-8, 1943.

Mattei, C., Tristani, M., and Barbe, A.: Aspect radiologique des cathétérismes zonaires du poumon au cours de la pénicillo-thérapie endobronchique des abcès pulmonaires, Presse méd. 54: 638, 1946.

Melnikoff, Alexander: Die chirurgische Anatomie des intrapulmonalen Gefässe und der Respirationswege, Arch. f. klin. Chir. 124: 460-510, 1922.

Neil, J. Hardie, Gilmour, W., and Gwynne, F. J.: The Bronchopulmonary Segments: Radiological, Pathological and Bronchoscopic Considerations, With Special Reference to the Subapical Bronchopulmonary Segment, M. J. Australia 2: 165-172, 1937.

Neil, J. Hardie, Gilmour, W., and Gwynne, F. J.: The Anatomy of the Bronchial Tree, Brit. M. J. 1: 495-498, 1939.

Nelson, H. P.: Postural Drainage of Lungs, Brit. M. J. 2: 251-255, 1934.

Scannell, J. Gordon: A Study of Variations of the Bronchopulmonary Segments in the Left Upper Lobe, J. THORACIC SURG. 16: 530-537, 1947.

Scannell, J. Gordon: An Anatomic Approach to Segmental Resection, J. THORACIC SURG. (In press.)

Scannell, J. G., and Boyden, E. A.: A Study of Variations of the Bronchopulmonary Segments of the Right Upper Lobe, J. THORACIC SURG. 17: 232-237, 1948.

AN ANALYSIS OF VARIATIONS OF THE SEGMENTAL BRONCHI OF THE LEFT LOWER LOBE OF FIFTY DISSECTED, AND TEN INJECTED, LUNGS

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INTRODUCTION

A SURVEY of the literature of the bronchopulmonary segments leaves one with the impression that the left lower lobe of the lung is a somewhat condensed or even defective version of the right lower lobe: that if one understands the pattern of the right side it is necessary to remember only one or two modifications—such as the union of medial and anterior basal bronchi—to comprehend the left.

Such at first was our experience. Soon, however, it began to appear that the left lobe, although capable of being compared with the right, is distinctive throughout. Thus, for instance, the rami of the left superior segment have a different system of branching, the left subsuperior *zone* is prevailingly posterolateral and not posterior, the left anterior basal and not the left medial basal is the "defective" bronchus, the lateral branch of the left lateral basal contributes to the subsuperior zone, and the left posterior basal, in a third of the specimens, is characterized by a *prominent* paravertebral ramus.

Hitherto, only Brock (1942 to 1944) seems to have made any detailed study of the variations of the lower lobe segments and he has largely confined himself to describing the varying extent of the segmental bronchi. Our purpose has been to establish the prevailing pattern in a large number of specimens and from this firm and hitherto unestablished base to analyze the significant and puzzling variations which are so frequently encountered.

In general, the terminology of Jackson and Huber (1943) has been employed, supplemented by the system of enumeration of bronchi developed by Boyden (1945). Also, throughout the article, the segmental pattern of the left lower lobe has been compared with that of the right, as recently presented by Smith and Boyden (1949).

MATERIAL AND METHODS

This study is based upon two sets of data: (1) a detailed dissection of fifty preserved specimens (R.M.B.) and (2) colored gelatin injections of ten fresh specimens (F.R.S.).

In the first group, each lobe was dissected from the anterior surface and then accurately drawn. Supplementary sketches recorded the projection of basal

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bronchi on the diaphragmatic surface, the bronchoscopic appearance of the orifices (here inverted), and the sectors supplied by various bronchi—particularly the subsuperiors (for example, text Figs. 5 and 6).

In the second group, fresh specimens were injected with colored gelatins (after the method employed in the study of the right lobe, Smith and Boyden, 1949), and then allowed to harden only one day or so before being dissected and drawn for publication (E.A.B.), for example, Plates 1 to 4.

By means of these two methods—dissection, and injection followed by dissection—it has been possible to establish the prevailing patterns and to display the common variations in the branching and surface distribution of the segmental bronchi.

THE GROSS CONFIGURATION OF THE LEFT LOWER LOBE

The left lower lobe has the shape of a cone, the upper part of which has been compressed. It is divided for descriptive purposes into four surfaces—namely, anterior, costal, paravertebral, and diaphragmatic.

The first two are separated by the sharp interlobar margin (Fig, 4, *B*, and *X*, Fig. 3), the second and third by an ill-defined obtuse margin—the costoparavertebral—which occupies the interval between the heads and tubercles of the ribs (Fig. 4, *B* and *Y*, Fig. 3), and the anterior and paravertebral by the pulmonary ligament and hilum.

The *anterior surface* (middle column of figures, Plate 1) is not a flat plane but exhibits a shallow S-shaped curve—that is, it is molded in such a way that the upper portion faces somewhat laterally and the lower portion somewhat medially. Usually, the lower portion is subdivided into cardiac and interlobar areas by the frenum* of the upper lobe (see Plate 1, No. 52). Usually, as in this plate, the frenum leaves the margin of the hilum between the superior and inferior pulmonary veins, but it may originate anywhere along the pulmonary ligament.† In several of the injected specimens it was coextensive with the pulmonary ligament, and the upper lobe was fused to the cardiac area of the lower lobe. In such cases (Plate 4) this lingular portion of the upper lobe was aerated by small branches of the medial basal bronchus.

The *costal surface* presents a smoothly rounded contour which may be divided arbitrarily—for the purposes of describing segments—into posterior, posterolateral, and lateral sectors (Fig. 4, *B*).

The *paravertebral surface* (Fig. 4, *B*) is molded to the posterior mediastinum and is markedly grooved by the descending aorta. As noted in the foregoing, the costoparavertebral margin is obtuse. For the purpose of describing segments, its position in the plates is indicated by a solid line (Plate 1, left row of figures).

In the course of this study various degrees of fusion between upper and lower lobes were observed. In the literature there is frequent mention of this condition—for example, Kent and Blades (1942) stated that the interlobar

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*A term introduced by Churchill and Belsey (1939).

†For more extended discussion, see article by Boyden, E. A.: Cleft Left Upper Lobes and the Split Anterior Bronchus, Surgery, 1949. (In press.)

EXPLANATION OF PLATES

(Sketches rendered for publication by Lawrence B. Benson)

Each plate contains five drawings each, of two injected specimens of the left lower lobe. The large figures at the left depict the costal surface of the lower lobe, the large central ones the anterior surface, and the large figures on the right the dissected anterior surface (each X ¼). In addition, there is a reduced drawing of the diaphragmatic surface (X ⅛) and a small sketch of the orifice of the basal trunk.

Yellow color indicates distribution of superior segmental bronchus (B^6); *white,* the subsuperior zone (B^* and BX^*); *blue* (primarily on anterior surface), the distribution of the medial basal segmental bronchus (B^7); *red,* the distribution of the anterior basal segmental bronchus; *blue* (primarily on costal surface), the distribution of the lateral basal segmental bronchus (B^9); *green,* the distribution of the posterior basal segmental bronchus (B^{10}). *Stippled* areas indicate cut surface of left upper lobe where it is fused with left lower lobe.

Plate 1.—*Specimen 52,* This is characteristically capped by an obliquely placed superior segment (B^6). Typical, also, is the subsuperior zone (B^*), in that it occupies the posterolateral sector of the costal surface. Its extension into the posterior sector is not typical (see Table IV). The basal segments demonstrate the prevailing pattern except that the anterior basal segmental bronchus (B^8) fails to reach the diaphragmatic surface. The two dorsal rami of the posterior basal, labeled (BX^*?), represent accessory subsuperiors which would have been branches of the *main* trunk of B^{10} had the latter not bifurcated so high (see BX^*[10] in No. 51).

Specimen 51, This is atypical in that B^6a2, the deep branch of the medial ramus of the superior bronchus, has displaced the subsuperior bronchus (B^*) lateralward, on the costal surface. Also the stem of B^{7+8} seems to have rotated medially, leaving that portion of the anterior surface which is usually supplied by B^8a to be taken over by accessory rami (BX^8a) of the subsuperior (B^*) and of the lateral basal (B^9). Accordingly, B^8 (and, to a lesser extent, B^7) supplies a much smaller than usual area.

Plate 2.—*Specimen 56,* This illustrates a subsuperior zone which is supplied by accessory subsuperior bronchi $BX^*(10)$ and $BX^*(9)$, from both the posterior and the lateral basal bronchi respectively. Since these usually arise at the top of their respective bronchi, the tip of the cannula usually projects beyond their orifices leaving the zone uninjected, as in this specimen. This lobe is of further interest in that the superior segment is partially separated from the basal segments by a fissure.

Specimen 58, This very much resembles No. 51 (Plate 1), in that B^6a2 has displaced the subsuperior zone laterally. (In this specimen the zone is supplied by an accessory subsuperior, BX^*, from the *posterior* basal, B^{10}.) Incidentally, there are two accessory subsuperiors from B^{10}, the second not quite reaching the subsuperior zone. Frequently, as here, a $BX^*(10)$ may arise conjointly with a paravertebral ramus of B^{10}. Also the anterior basal (B^8) encroaches on the medial basal (B^7), but in this case B^7a is present.

Plate 3.—*Specimen 55,* This has a subsuperior zone which is almost a duplicate of that in No. 53 except that it is supplied by two accessory subsuperiors from different sources—namely, high branches of both B^{10} and B^9. The anterior basal (B^8) is represented by both of its rami, but again fails to reach the diaphragmatic surface. Here the medial basal is separated from the other basal segments by a deep fissure, best shown on the diaphragmatic surface. Such fissures are not uncommon (25 per cent).

Specimen 53, Here the subsuperior zone is supplied by a high accessory branch (BX^*) of B^{10} which is almost high enough to be a subsuperior proper. Also, it distributes to the posterior as well as the posterolateral sector of the zone, since B^6a2 is absent. Also in this specimen, the basal ramus of the anterior basal (BX^8b) arises as an accessory branch of the lateral basal (B^9). Therefore B^8 appears to be restricted to a small area on the mid-anterior surface (B^8a).

Plate 4.—These specimens exhibit a fusion of the upper lobe with the lower lobe, the area of fusion extending a varying distance laterally from the whole length of the pulmonary ligament. In each case the thin portion of the lower lingular segment (B^5) was aerated by small accessory branches (BX^5) of the medial basal (B^7). The specimens are also similar in that the basal ramus of B^8 arises as an accessory branch (BX^8b) of the medial basal (B^7).

Specimen 60, Here the subsuperior zone is very extensive, being supplied by a large subsuperior proper (B^*) and two accessory subsuperiors $BX^*(9)$ and $BX^*(10)$. The last of these arises in conjunction with a paravertebral branch of the posterior basal. Also the lateral ramus of the superior segment (B^6c) has what appears to be displaced branches of the superior ramus (B^6b?). This is the "cluster type" of branching noted in Table I.

Specimen 54, This is characterized by three accessory subsuperiors (BX^*), one from the top of the lateral basal (B^9), and two from different levels on the posterior basal (B^{10}). Although one of the last two arises some distance below the other, they both distribute to the same level. The zone as a whole is somewhat depressed by a large B^6a2. In this specimen, the medial ramus of the medial basal arises as an accessory branch of B^9 (see BX^7b).

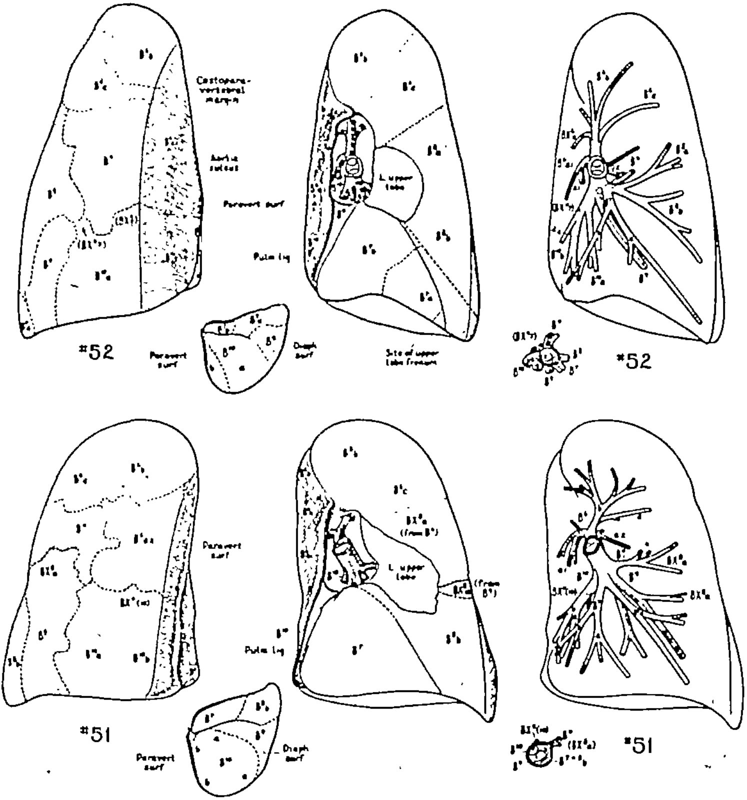
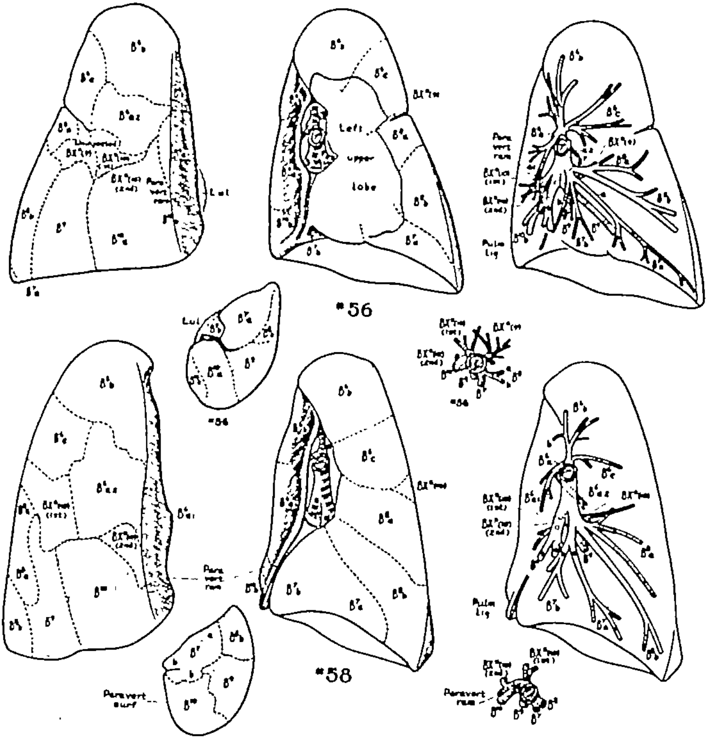
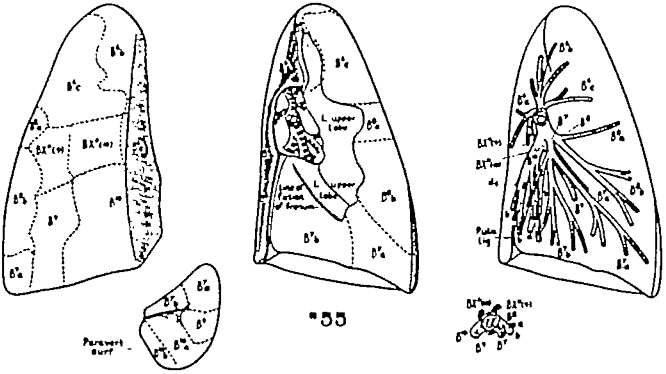

Costopara-vertebral margin
Aortic sulcus
Paravert surf
Pulm lig
L upper lobe
Paravert surf
Diaph surf
Site of upper lobe fissure
#52
#52
Paravert surf
L upper lobe
(from B⁹)
Pulm lig
Paravert surf
Diaph surf
#51
#51

Plate 1.

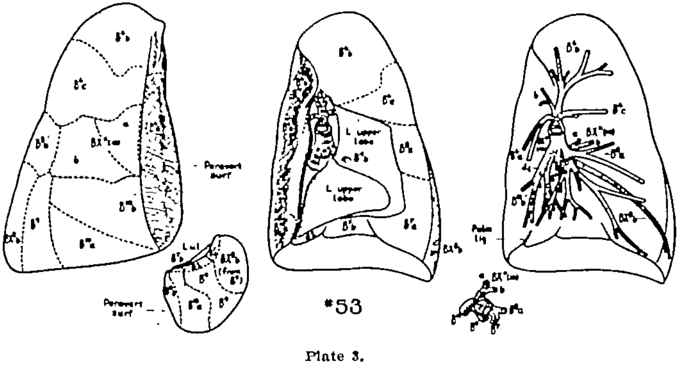


Left upper lobe
Lul
Para vert ram
Pulm lig
#56
#58
Paravert surf
Paravert ram

Plate 2.


Paravert surf
L upper lobe
L upper lobe
Line of fusion of fissure
Pulm lig

#55


Paravert surf
Paravert surf
L upper lobe
L upper lobe
Pulm lig

#53

Plate 3.

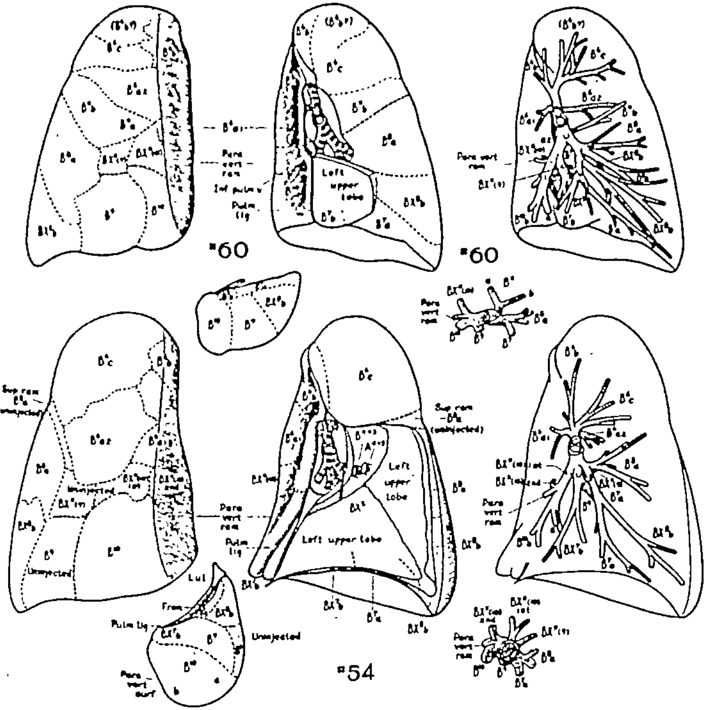

#60
#60
Para vert ram
Inf pulm v
Pulm lig
Left upper lobe
Para vert ram
Sup ram B6a (uninjected)
Uninjected
Left upper lobe
Para vert ram
Pulm lig
Left upper lobe
Sup ram B6a (uninjected)
Para vert ram
Lat
Fron
Pulm lig
Uninjected
Para vert surf
#54

Plate 4.

fissure was incomplete in about 30 per cent of 277 lungs, being equally common on each side.

THE SUPERIOR SEGMENTAL BRONCHUS (B^6)

The superior bronchus arises just below the upper lobe bronchus in such a position as to complicate resection of the lower lobe, that is, its keel lies only 1 cm. below the keel of the lower lobe bronchus. It is the highest dorsal branch of the lower lobe and therefore has been considered by Brock to be the principal site of lung abscess in this lobe. As on the right side, it breaks up into three constant rami—the medial branch (B^6a) running medially and downward, the superior branch (B^6b) running upward, and the lateral branch (B^6c) coursing laterally and somewhat downward.

In mode of branching the prevailing pattern of B^6 agrees with that of the right side in being bifurcate, but differs in the formula. On the left it usually divides into B^6a and $B^6b + c$ (43 per cent of specimens; Fig. 1, No. 37); on the right it divides into B^6c and $B^6a + b$ (86 per cent).* The percentages indicate that the branching on the left side is more variable than on the right, while the lower and independent origin of B^6a suggests that the paravertebral extent of the bronchus will be much greater on the left side (vide infra).

The frequency of the various types of branching is indicated in Table I. The type recorded in Item I: 2 (see Fig. 1, No. 4) is the one considered most "normal" by Brock (1943). That in Item I: 3 (see Fig. 1, No. 48) is the one described for the left side by Ewart (1889). This is the prevailing pattern on the right side. No one seems to have observed what is termed the "cluster type" (Item I: 4, see Plate 4, No. 60). Here, B^6b is represented by more than one main branch.

Trifurcation of B^6 is relatively uncommon (15 per cent; Fig. 1, No. 55), but not so rare as on the right side (6 per cent).

TABLE I. THE SUPERIOR SEGMENTAL BRONCHUS (B^6)

I. Bifurcates Into:			85%
1. B^6a and $B^6b + c$	(Fig. 1, No. 37)	43%	
2. B^6b and $B^6a + c$	(Fig. 1, No. 4)	27%	
3. B^6c and $B^6a + b$	(Fig. 1, No. 48)	10%	
4. Cluster type		5%	
(1) $B^6a + b$ and $B^6b + c$			
(2) B^6a and $B^6b + (B^6b + c)$ (Plate 4, No. 60)			
(3) B^6b and $(B^6b + c) + B^6a$			
II. Trifurcates Into B^6a, B^6b, B^6c (Fig. 1 and Plate 3, No. 55)			15%

The distribution of the superior bronchus is much like that on the right side but differs in at least two particulars. First, in the majority of left lower lobes the superior segment caps the basal segments very obliquely, thus presenting an anatomic hazard to the resection of this segment. (On the right the segment is horizontally placed in 62 per cent.) This is due to the fact that the medial ramus (B^6a) extends downward along the paravertebral surface to within a short distance of the diaphragmatic surface—specifically, it reaches the lower third or less of the paravertebral surface in 57 per cent of specimens (for example, Plate 3, No. 53).*

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*The statistics for the right side which will be referred to frequently are those published by Smith and Boyden (1949).

Second, in 45 per cent of left lower lobes, there is a large posterior branch (B^6a2) which takes over the posterior sector of the subsuperior zone. It is represented occasionally on the right side by a deep branch of B^6a, but on the left it is so striking as to merit a special designation (B^6a2, Fig. 1, No. 37 and Plate 4). In certain specimens in which B^6a2 is absent, its territory is taken over by a large, posterior descending branch of B^6c as in Fig. 1, No. 48. (See discussion of subsuperior zone.)

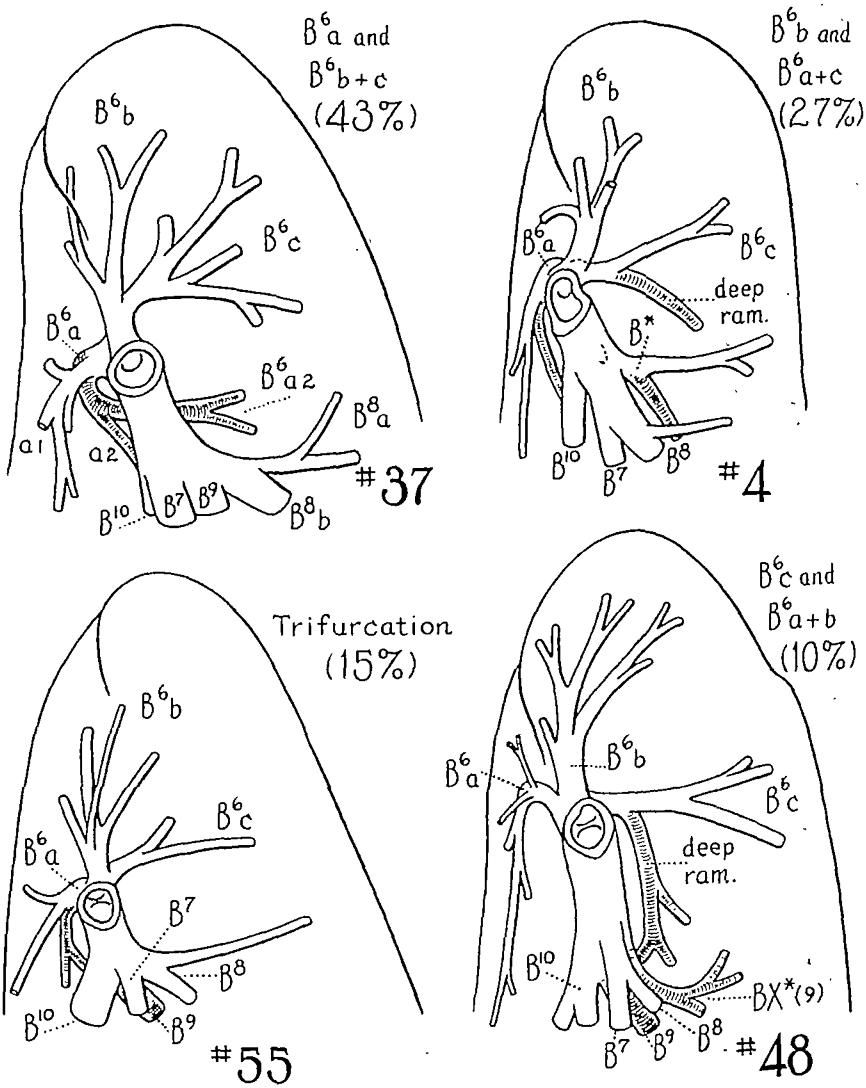

Fig. 1.—Selected drawings illustrating mode of branching of the superior segmental bronchus (X ½). (B^6a, medial ramus; B^6b, superior ramus; B^6c, lateral ramus.) In addition, specimen No. 37 shows a deep branch of ramus *a* (B^6a2) which occurs in 45 per cent of specimens; No. 48 illustrates a deep branch of ramus *c* (*deep ram.*), which occurs in 18 per cent of specimens.

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*This finding is, therefore, at variance with the statement of Huizinga and Behr (1940) that "the lower limit of this dorsal segment is always horizontal."

B^6a is of further interest in that in 13 per cent of specimens, part of its *paravertebral territory is taken over by an accessory branch of the superior ramus* (for example, BX^6a, Fig. 6, No. 23; Plate I, No. 52); in another 2 per cent the lower two-thirds of the paravertebral surface is taken over by a high accessory branch of B^{10}. The distribution of these accessory branches is indicated in the footnote to Table II.

TABLE II. LOWEST EXTENT OF MEDIAL RAMUS (B^6a) ON THE PARAVERTEBRAL SURFACE

Two-thirds or more of distance to diaphragm (Plate 3, No. 53)	57%*
Halfway to diaphragm (Plate 4, No. 60)	37%
One-third of distance to diaphragm	3%
Fails to reach paravertebral surface and is replaced by a branch of B^6b	3%

*In 8 per cent the upper portion of paravertebral surface is replaced by an accessory branch of B^6b. Since this occurs altogether in only 15 per cent of specimens it would seem that when the medial ramus descends the lowest there is a tendency for its upper territory to be taken over by B^6b.

Discussion of this segment should *not* be concluded without mentioning the occurrence of a notch on the lateral side of the interlobar margin of the lobe which marks the separation of the superior from the basal segments in 5 per cent of specimens (Fig. 6, No. 8; Plate 2, No. 56) and of an extensive fissure recently observed in an autopsy specimen. This is a much lower frequency than was reported by Dévé in his study of 180 infants (14 per cent on the left, 30 per cent on the right, 12 per cent bilateral). Pierret, Coulouma, Breton, and Devos (1938) did not give separate figures for the two sides but reported the occurrence of the fissure in 20 per cent of specimens. Nelson (1934) considered that this inconstant fissure provided supporting evidence for his classification of the superior segment as a separate lobe, but it would seem that the fissure is no longer necessary to the argument.

THE SUBSUPERIOR BRONCHUS (B^*)

On the right side the subsuperior bronchus has been identified as the second dorsal ramus of Aeby, that one which arises from the stem bronchus between the first dorsal or superior bronchus (B^6) and the origin of B^9 (B^*, Fig. 2, *A*). On that side, it usually supplies the region which occupies the interval between the superior and the *posterior basal segments in the posterior sector of the costal surface*. On the left side, we will show that it arises from the same portion of the stem bronchus (B^*, Fig. 2, *B*), is distributed to the same horizontal level, but that it supplies the posterolateral sector.

Neil, Gilmour and Gwynne (1937) were the first modern investigators to call attention to this "site of localized pathological change—an anatomical gap in the distribution between the apical [B^6] and paravertebral [B^{10}] bronchi." When this bronchus was absent they noted that the "subapical segment" was supplied by a branch of the posterior basal (B^{10}). Smith and Boyden (1949) confirmed these observations and named the two types of bronchi that supply this intermediate zone the *subsuperior proper*, B^*, and the *accessory subsuperior*, $BX^*(10)$.† Because of the prevailingly dual and variable bronchial supply,

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†Interpolation of the letter "X" indicates that the bronchus supplying a given zone arises from another portion of the bronchial tree than is customary. The figure in parentheses tells its new site of origin. Thus "$BX^*(10)$" indicates that the subsuperior zone is supplied by a high branch of B^{10} instead of by the second dorsal branch of the stem bronchus.

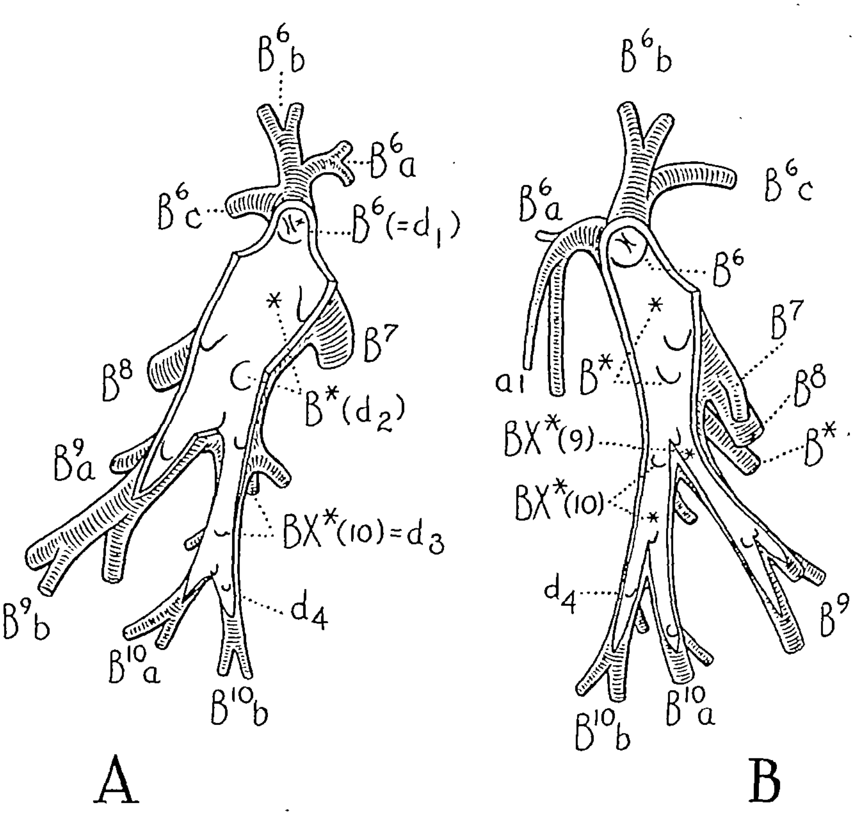


Fig. 2.—Sketches comparing the sites of origin of dorsal branches of the stem bronchus in left and right lower lobes. *B*, drawing of left side (specimen No. 50). *A*, drawing of right side after Smith and Boyden (1949). The specimen in *A* has five dorsal rami; the site of a possible sixth is noted by an asterisk. These have been grouped into four levels, corresponding to the four dorsal bronchi postulated by Aeby, in 1880. The first level (d_1) is the site of the superior segmental bronchus (B^6); the second (d_2), the site of the subsuperior proper (B^*); the third (d_3), the site of the accessory subsuperior (BX^*). The orifices of corresponding dorsal bronchi on the left side are shown in B. The principal difference between the two sides as that on the left the dorsolateral branch of B^9 (BX^*[9]) also participates in the subsuperior zone (see discussion in text).

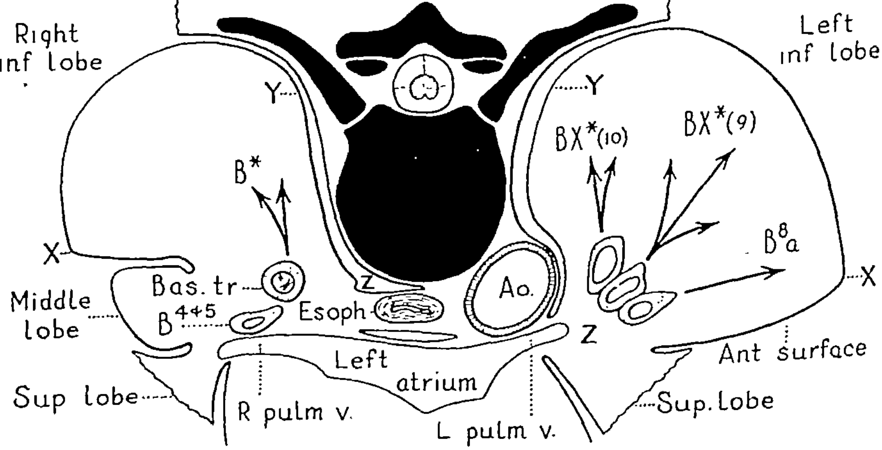


Fig. 3.—Transverse section of the lower lobes of an intact thorax to illustrate the differing direction of the subsuperior bronchi on the two sides. On the right, the subsuperior proper (B^*) distributes primarily to the posterior sector of the costal surface; on the left, it may distribute to the posterior sector (see BX^* from B^{10}), but prevailingly it has a posterolateral distribution (see BX^* from B^9). BX^*(10) and BX^*(9) are left accessory subsuperiors, arising just beneath the left subsuperior proper (B^*), which does not appear in this figure. *X*, interlobar margin of lower lobe; *Y*, costoparavertebral margin; *Z*, hilum (or, lower down, the pulmonary ligament).

they did not follow Neil in giving this zone the status of a segment, or numbering it—hence the noncommittal designation B*.

On the left side, this intermediate zone is equally conspicuous and clinically significant, but the bronchi supplying it are more numerous. In a later article (1939) Neil and his co-workers stated that the subapical bronchus [B*] "may be absent on the left side, in which case we have found a branch going to its customary distribution arising from the axillary basal [B^9] or from the posterior basal [B^{10}]." With this conclusion we would also agree, but it would seem that the evidence supporting it has yet to be presented.

In the first place, analysis of the 60 specimens indicates that on the left side, as contrasted with the right, the subsuperior proper (B*) always distributes to at least the posterolateral sector and most commonly to both the posterolateral and lateral sectors of this intermediate zone (see Table IV, Item IV), whereas on the right side it is distributed primarily to the posterior sector (B*, Fig. 3). Furthermore, the angle it makes with the anterior surface is prevailingly 40 to 45 degrees (23 per cent; see Table IV, Item III: 1).

For this reason, both the uppermost dorsal branches of B^9 and B^{10} that enter into the composition of the subsuperior segment must be considered acces-

TABLE III. OCCURRENCE OF SUBSUPERIOR BRONCHI (B* AND BX*)

				In 50 rt. lower lobes‡
I. Frequency of Occurrence in 60 Left Lower Lobes†				
1. Origin exclusively from level d_1 (as branch of main lower lobe bronchus between the superior and basal bronchi)			7%	14%
2. Origin exclusively from level d_2 (as an accessory subsuperior, BX*(10) or BX*(9)			71%	38%, BX*(10)
3. Origin from both levels in same specimen			22%	48%
			100%	100%
II. Detailed Analysis				
1. Subsuperior represented by single bronchus			22%	50%
(1) Arising at d_1 level (as B*)		7%		(14%)
(2) Arising at d_2 level (as BX*)		15%		(34%)
(a) From top of B^{10}	8%			
(b) From top of B^9	7%			
2. Subsuperior represented by two bronchi			61%	34%
(1) One from level d_1(B*) and one from level d_2(BX*)		13%		(32%)
(a) B* and BX*(10)	11%			
(b) B* and BX*(9)	2%			
(2) Two from level d_2 (BX*)		48%		(2%)
(a) BX*(9) and BX*(10)	43%			
(b) Two BX*(10)	5%			
3. Subsuperior represented by three bronchi			17%	14%
(1) Two from level d_1(B*) and one from level d_2, BX*(10)		2%		
(2) One from level d_1(B*) and two from level d_2, BX*(10) and BX*(9)		7%		
(3) Three from level d_2 Two BX*(10) and one BX*(9)		8%		
4. Subsuperior represented by four bronchi (two from each level)			0%	2%
			100%	100%

†Percentages in round numbers.

‡Data from Smith and Boyden (1949).

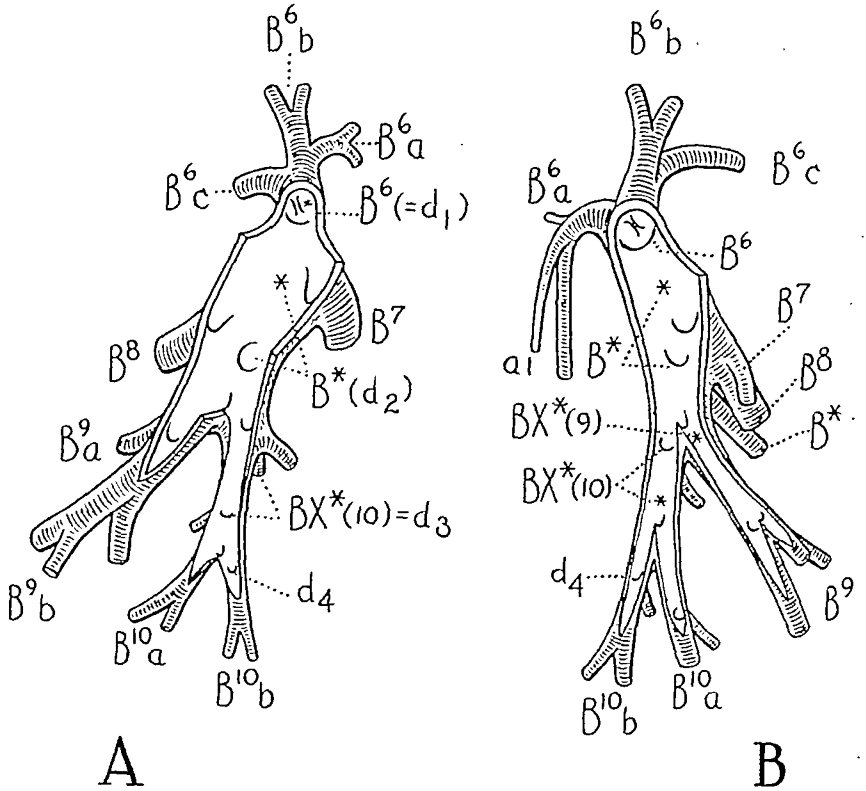


Fig. 2.—Sketches comparing the sites of origin of dorsal branches of the stem bronchus in left and right lower lobes. *B*, drawing of left side (specimen No. 50). *A*, drawing of right side after Smith and Boyden (1949). The specimen in *A* has five dorsal rami; the site of a possible sixth is noted by an asterisk. These have been grouped into four levels, corresponding to the four dorsal bronchi postulated by Aeby, in 1880. The first level (d_1) is the site of the superior segmental bronchus (B^6); the second (d_2), the site of the subsuperior proper (B^*); the third (d_3), the site of the accessory subsuperior (BX^*). The orifices of corresponding dorsal bronchi on the left side are shown in B. The principal difference between the two sides as that on the left the dorsolateral branch of B^9 ($BX^*[9]$) also participates in the subsuperior zone (see discussion in text).

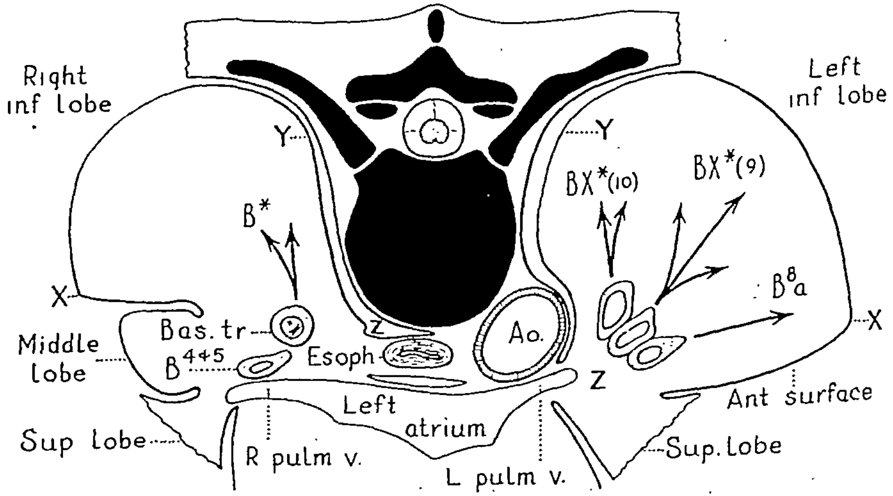


Fig. 3.—Transverse section of the lower lobes of an intact thorax to illustrate the differing direction of the subsuperior bronchi on the two sides. On the right, the subsuperior proper (B^*) distributes primarily to the posterior sector of the costal surface; on the left, it may distribute to the posterior sector (see BX^* from B^{10}), but prevailingly it has a posterolateral distribution (see BX^* from B^9). $BX^*(10)$ and $BX^*(9)$ are left accessory subsuperiors, arising just beneath the left subsuperior proper (B^*), which does not appear in this figure. *X*, interlobar margin of lower lobe; *Y*, costoparavertebral margin; *Z*, hilum (or, lower down, the pulmonary ligament).

have defined as the d_2 level. In 5 per cent it originates from the highest position indicated in Fig. 2, *B*, that is, above the origin of $B^{7 \text{ and } 8}$; in the remaining 24 per cent it arises from the common stem of B^{9+10}.

Its position on the circumference of the basal stem is varied. In 12 per cent its orifice is posterior (or slightly posterolateral); in another 12 per cent it is posterolateral; and in 5 per cent it is lateral (or slightly posterolateral). (See Table IV, Item II.) Neil and co-workers (1939) "found it situated dorsally, medially, laterally and twice ventrally." Neil's medial subsuperior is presumably one of the high accessory subsuperiors, BX*(10), which occasionally arises medially in conjunction with a high paravertebral branch of B^{10} (Fig. 6, *E* and Plate 4, No. 60). Neil's ventral subsuperior could have been a high B^8a with posterolateral branches.

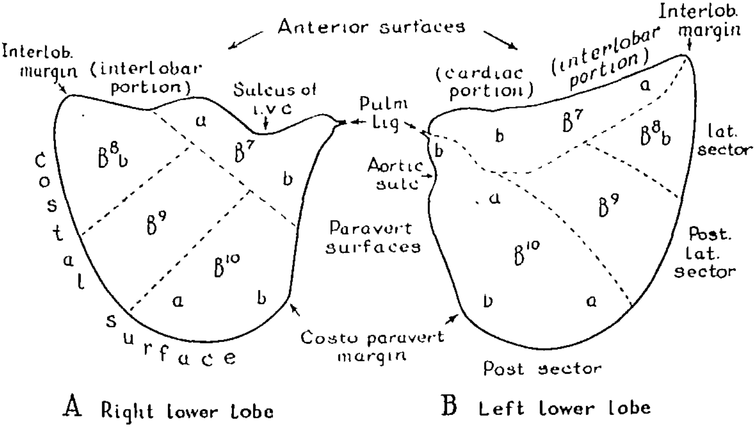


Fig. 4.—Diagrams illustrating typical arrangement of basal segments in a cross section of the lower lobes made just above the diaphragm, and viewed from below. *A, right lower lobe* (after Smith and Boyden). Note that the medial basal segment (B^7) is placed athwart the other segments and that the latter overlap each other as postulated by Melnikoff. *B, left lower lobe,* illustrating shift in position of B^7: on this side it lies wholly lateral to the pulmonary ligament, failing to reach the paravertebral surface. That site is now occupied by the posterior basal segment (B^{10}); nevertheless, B^7 is as extensive as on the right. Note that the basal ramus of the anterobasal segment (B^8b) supplies the lateral sector of the costal surface; that the lateral basal segment (B^9) supplies the posterolateral sector; and that the posterior basal (B^{10}) supplies the posterior sector and the paravertebral surface.

This brings out the point that it is often hard to distinguish between a laterally originating B* (for example, Fig. 7, No. 4) and the lateral ramus of the anterior basal bronchus, B^8a (for example, Fig. 7, No. 41). In the former case, a lateral B* distributes primarily to the posterolateral sector of the subsuperior zone but it has branches that take over the upper anterolateral zone (BX*a). Superficially the two specimens look somewhat alike, but when the orifice of B* is noted (Fig. 7, *D*), the bronchus is seen to arise more posterolaterally, behind B^9.

In Fig. 5, specimen No. 39 is somewhat similar, but here (Fig. 5, *H*) the orifice of the subsuperior bronchus is posterior, that is, behind all basal bronchi.

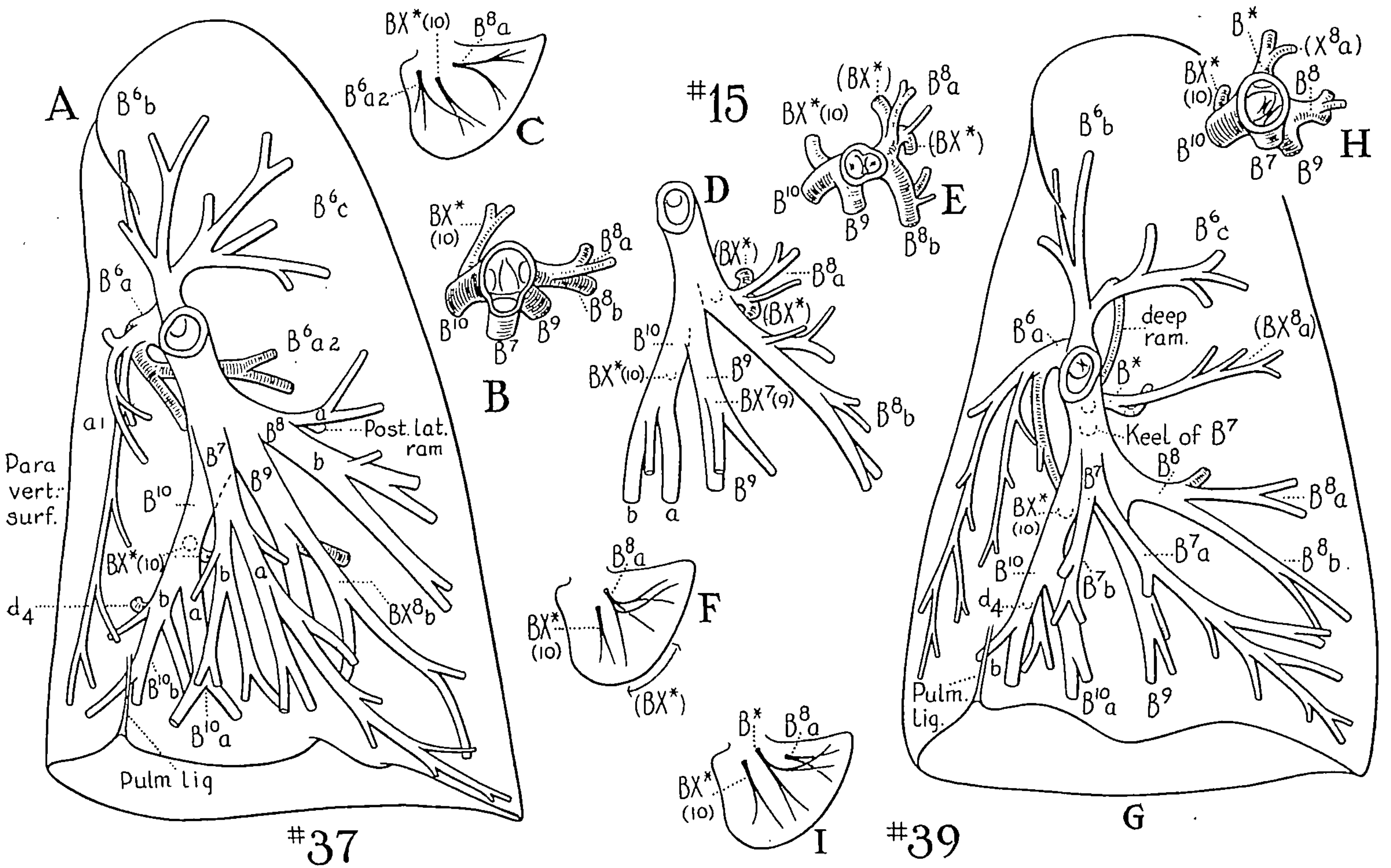
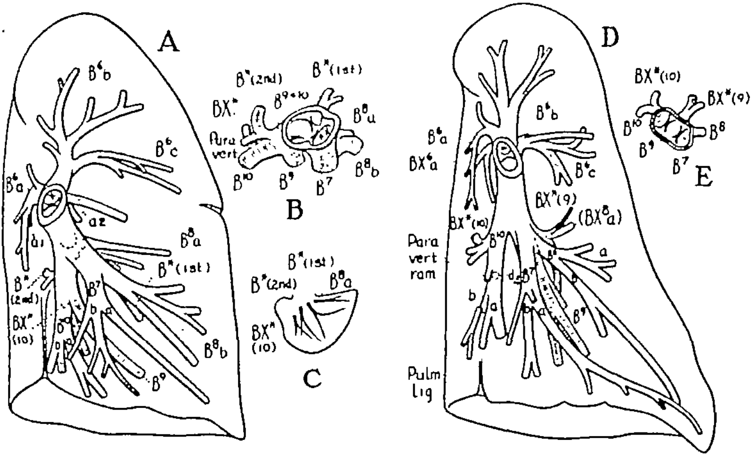


Fig. 5.—Drawings of the bronchial trees of three preserved left lower lobes (X¼) to show (1) transitional patterns between B⁶a and B*; (2) anomalous origins of B⁷ and B⁸. *A*, *B*, *C* anterior dissection, orifice of basal trunk, and cross section, respectively, of specimen No. 37. B⁸ is typical except for a posterolateral ramus that simulates the distribution of a subsuperior; B⁷ arises separately, as in the right lower lobe; B⁹ takes over part of the territory of B⁸b (see BX⁸b). *D*, *E*, *F* are corresponding views of specimen No. 15. B⁸a is atypical in that it has an accessory subsuperior rami (BX*). B⁷ (as BX⁷) arises anomalously from the lateral basal (B⁹). *G*, *H*, *I* are corresponding views of specimen No. 39. B* (the subsuperior) takes over part of the territory of the lateral ramus of B⁸ (see BX⁸a). B⁷ again arises separately from B⁸.

It is a subsuperior both because of its origin and because of its distribution; yet, again there is a secondary distribution to the B^8a zone.

In specimen No. 15 (Fig. 5) the situation is reversed. Here the corresponding bronchus has a lateral origin in common with B^8b and therefore its main stem must be designated B^8a. The deeper portion of it, which distributes to the subsuperior zone, may be called a displaced subsuperior, $BX^*(8)$. In specimen No. 37, B^8a makes a lesser contribution to the subsuperior zone (see Fig. 5, *C*) and therefore is merely designated B^8a.



#8 #23

Fig. 6.—Drawings of two preserved specimens (X ⅔) illustrating the prevailing (bifurcate) and atypical (trifurcate) mode of division of the basal trunk. *A*, *B*, *C*, are anterior dissection, orifice of basal trunk, and cross section, respectively, of specimen No. 8. The trunk bifurcates into an anterior (B^{7+8}) and a posterior division (B^{9+10}). *D*, *E*, are anterior dissection and orifice, respectively, of specimen No. 23, showing a trifurcation into three stems, B^{7+8}, B^9, and B^{10}. Incidentally, these figures show how a high division of B^9 and B^{10} may convert a subsuperior proper (B^*, 2nd, of No. 8) into an accessory subsuperior ($BX^*[10]$, of No. 23).

Brock also realized the difficulty of describing these transitional forms. His solution for handling a laterally originating B^* like that in Fig. 7 (No. 4), is to call it a "supernumerary axillary anterior basic bronchus," as if it were the axillary (lateral) ramus of B^8 which had arisen higher than usual—that is, from the main stem. In his own words he preferred "to restrict the name subapical [subsuperior] to the one inconstant but commonest, posterior bronchus and to name and describe any others separately (see axillary branches, p. 63)." However, he apparently did not realize that the one inconstant subsuperior bronchus arising from the lower lobe stem on the left side distributes to the posterolateral sector. Thus, if his preference were followed, most left subsuperiors would have to be called supernumerary axillary middle basals, which would destroy the useful concept of an intermediate zone interpolated between the superior and basal segments. Furthermore, Brock's use of the term axillary to cover bronchi distributing to lateral, posterolateral, and posterior sectors of the lower lobe, while having perhaps a certain clinical value, is not precise enough to be of use in analyzing patterns.

2. *The Accessory Subsuperior, $BX^{*}(10)$.*—An accessory subsuperior arises as a single branch of the posterior segmental bronchus (B^{10}) in 71 per cent of specimens and as two separate rami in 13 per cent. When single its keel lies typically within a distance of 12 mm. below the keel separating B^{9} and B^{10}. When two are present they originate at the levels shown in Fig. 2, *B*, but may distribute to the same surface level (Plate 4, No. 54). In view of the marked lateral shift of B^{*} on the left side, it is interesting to note that $BX^{*}(10)$ also distributes to a posterolateral sector in one-half of the specimens in which it occurs (Fig. 5, *C*, No. 37). This is in marked contrast to its behavior on the right side, where it invades the posterolateral sector in only about one-sixth of the cases in which it is the only subsuperior present. The percentages for the left side are given in Table V.

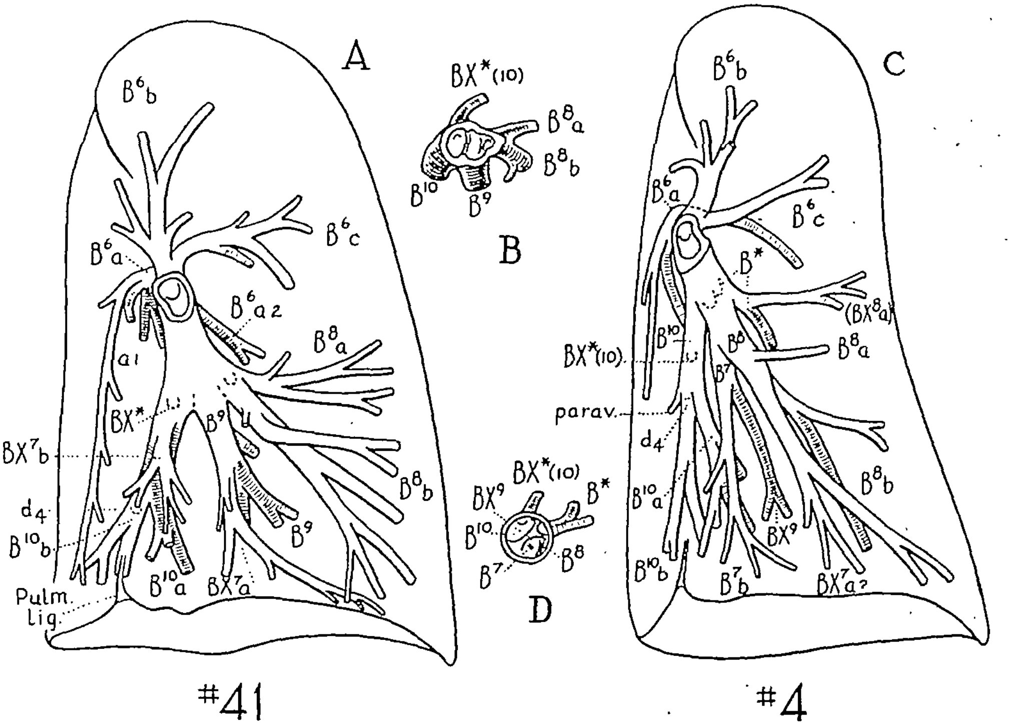


Fig. 7.—Sketches of two preserved specimens (X ½) illustrating bizarre origins of the medial and lateral basal bronchi, B^{7} and B^{9}. *A, B,* are anterior dissection and orifice of basal trunk of No. 41. $B^{7}a$ (as $BX^{7}a$) arises as an accessory branch of B^{9}. $B^{7}b$ (as $BX^{7}b$) originates as an accessory branch of B^{10}. *C, D,* are corresponding views of specimen No. 4. B^{9} (as BX^{9}) arises as an accessory branch of a deep-lying B^{7}.

3. *The Accessory Subsuperior $BX^{*}(9)$.*—An accessory subsuperior arises in 67 per cent of specimens from near the top of the lateral basal segmental bronchus (B^{9}). Like $BX^{*}(10)$ its keel lies typically within 12 mm. of the distance below the keel of B^{9} and B^{10}. Prevailingly it distributes to the posterolateral sector (see Table VI) and, as would be expected, makes an angle of about

TABLE V. DISTRIBUTION OF $BX^*(10)$

I. Sector	
1. Wholly posterior (Plate 4, No. 60)	41%
2. Posterior and posterolateral (Plate 3, No. 53)	26%
3. Posterolateral only	16%
4. Posterolateral and lateral (Plate 2, No. 58)	1%
II. Angle With Anterior Surface of Lobe	
1. 75-100 degrees (Plate 2, No. 58)	61%
2. 45-50 degrees (Fig. 7, *B*)	23%

45 degrees with the anterior surface in the majority of specimens (see Fig. 3). However, it has a strong tendency to shift laterally. In this respect it resembles the subsuperior proper (see Table IV). It is homologous with B^9a of the right lobe, but on the right side B^9a does not usually participate in the subsuperior zone, since the subsuperior zone of the right lung is primarily restricted to the posterior sector.

TABLE VI. DISTRIBUTION OF $BX^*(9)$

I. Sector	
1. Posterolateral only (Plate 4, No. 54)	40%
2. Posterolateral and lateral (Plate 3, No. 55)	14%
3. Posterior, posterolateral, and lateral	5%
4. Posterior and posterolateral	8%
II. Angle With Anterior Surface of Lobe	
1. 40-60 degrees (Plate 2, No. 56)	45%
2. 20-35 degrees	12%
3. 70-90 degrees (Plate 3, No. 55)	10%

To summarize this sector, it has been pointed out that the criterion for defining the subsuperior zone has been the prevailing distribution of the subsuperior bronchus proper (B^*). On the right side, it is prevailingly posterior, and on the left, prevailingly posterolateral. Any additional bronchi that regularly distribute to this zone have therefore been called accessory subsuperiors, notably $BX^*(10)$ on both sides and $BX^*(9)$ on the left. Certain other extraneous branches that sometimes invade the posterior or lateral sector of this zone—such as the more posterior rami of B^6a, B^6c, and B^9a—might perhaps be included. Indeed, Ewart describes "a central lozenge-shaped bronchial interspace" in the left lower lobe formed by "the lesser posterior horizontal [$BX^*(10)$] . . . together with the external mammary [B^9a] and the midaxillary bronchus [$BX^*(9)$]." However, it seems sufficient to point out that such extraneous branches may invade this zone and to note the criteria by which they may be distinguished from the true subsuperior and the more frequently occurring accessory subsuperiors.

THE BASAL BRONCHI

The subdivision of the basal trunk below the level of the superior bronchus (B^6) is somewhat different on the left side from that on the right. On the left the medial basal segmental bronchus (B^7) arises more anterolaterally and usually in conjunction with the anterior basal (B^8), instead of being the highest and most medial basal bronchus. For this reason various recent authors have considered B^7 and B^8 collectively as a single segmental bronchus. Here, for purposes of description, at least, they will be treated separately.

TABLE VII. MODE OF BRANCHING OF BASAL TRUNK*

I. Basal Trunk Bifurcates			87%
1. Into B^{7+8} and B^{9+10} (Fig. 6, No. 8)		67%	
2. Into bizarre patterns		20%	
(1) B^7 and B^8 + (B^{9+10}) †(Fig. 5, No. 37)	8%		
(2) B^{10} and B^8 + (B^{7+9}) (Fig. 7, No. 4)	7%		
(3) B^7 and (B^{8+9}) + B^{10} (Fig. 5, No. 39) B^8 and (B^{9+7}) + B^{10} (Fig. 5, No. 15) B^{7+8a} and $B^8b + {}^{10}$ (B^9 absent)	5%		
II. Basal Trunk Trifurcates‡			
Into B^{7+8}, B^9, and B^{10} (Fig. 6, No. 23)			13%

*The subsuperiors are ignored in this classification, together with such minor branches as high paravertebral branches of B^{10}.

†Resembles typical pattern of right basal trunk.

‡Counted as a trifurcation when keels were not more than 4 mm. apart. In another 7 per cent the keels were a few millimeters further apart.

Below the point of origin of B^{7+8}, the basal trunk continues as the common stem of the lateral and posterior segmental bronchi (B^9 and B^{10}, respectively). In other words the prevailing pattern, contrary to what has hitherto been supposed, is a bifurcation of the basal trunk into B^{7+8} and B^{9+10} (Fig. 6, No. 8).* Trifurcations occur in only 13 per cent (Fig. 6, No. 23). The percentages and varying combinations are recorded in Table VII.

THE MEDIAL BASAL SEGMENTAL BRONCHUS (B^7)

The medial basal bronchus arises in common with the anterior basal (B^8), or one of its two branches, in 87 per cent of specimens (Table VIII). This short stem emerges from the anterolateral aspect of the basal trunk. Prevailingly (47 per cent), B^7 lies somewhat anterior to B^8 (Fig. 6); frequently (35

TABLE VIII. THE MEDIAL BASAL BRONCHUS (B^7)

I. Origin			
1. Arises in common with B^8 (or one of its rami)*			87%
(1) B^7 lies in plane anterior to B^8	47%	(Fig. 6)†	
(2) B^7 and B^8 lie in same plane	35%	(Plate 1, No. 52)	
(3) B^7 lies deep to B^8	5%	(Fig. 7, No. 4)	
2. Arises separately from B^8 on anterior side of main stem (Fig. 5, No. 37, No. 39)			10%
3. Absent as such but occurs as accessory ramus of B^9 or as rami of B^9 and B^{10} (Fig. 5, No. 15; Fig. 7, No. 41)			3%
II. Distribution			
1. Supplies the whole width of the inferior portion of anterior surface (Plate 3, No. 53)			55%
2. Supplies medial ½ to ⅔ of inferior portion of anterior surface (Plate 2, No. 58)			20%
3. Supplies the whole inferior portion of anterior surface and also a sector of costal surface			17%
(1) By spreading of its branches (Plate 3, No. 55)		10%	
(2) By virtue of accessory rami (BX^9 or BX^8b) (Plate 4, No. 60)		7%	
4. Supplies medial ½ to ⅔ of inferior portion of anterior surface and also a costal sector (BX^9 or BX^8b) (Fig. 7, No. 4)			5%
5. B^7 absent as such; represented by accessory rami of adjacent bronchi (Fig. 7, No. 41)			3%

*In one specimen B^7 was represented in its usual place by only one of its two rami, B^7a; the other ramus, B^7b was displaced, arising as an accessory branch of B^9 (plate 4, No. 54).

†In one specimen B^7 and B^8a arose together, more anteriorly than B^8b.

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*Davis (1929) found a trifurcate pattern in 53 per cent of 32 lungs.

per cent), it lies in the same plane (Plate 1); rarely (5 per cent) it lies deep to B^8 (Fig. 7, No. 4).

Of special interest are the 10 per cent of specimens in which B^7 arises separately from the basal trunk thereby simulating the appearance of its homologue in the right lung. Two such specimens are displayed in Fig. 5 (No. 37 and No. 39). Dévé (1900) was the first to describe this pattern and De Pablo (1940), Hagens (1943), and Foster-Carter (1946) have reported it more recently.

In 3 per cent, B^7 is absent from its usual position, arising as an accessory ramus of B^9 or as rami of B^8 and B^{10} (Fig. 5, No. 15; and Fig. 7, No. 41).

Since the typical pattern in the left lung is characterized by a common origin of B^7 and B^8, many different views have been held with respect to the nature of B^7. Some authors (Aeby, Kramer and Glass, Nelson, Neil, etc.) stated that B^7 is not represented in the left lower lobe. Others (Pierce and Stocking, 1939, Foster-Carter, 1942, Adams and Davenport, 1942, Jackson and Huber, 1943, Brock, 1943, etc.) relegate it to the status of a subsegmental bronchus or less. Only a few investigators, Lucien and Weber (1936), De Pablo (1940), Appleton (1944), *etc., maintain that* B^7 *is a distinct segmental* bronchus.

On the basis of its distribution in the sixty specimens presented in this study, we have reluctantly come to the conclusion that it should be considered as a major bronchus. The mere fact that it arises in conjunction with B^8 is no more relevant than the fact that the segmental bronchi of the middle lobe have a common stem.

When the typical distribution of the left medial basal bronchus is compared with the right medial (Fig. 4), it will be noted that the two bronchi aerate an equally large zone. The difference is that on the left B^7 has shifted laterally. Instead of supplying part of the paravertebral surface and part of the anterior surface, it has withdrawn from the paravertebral surface (contrary to Lucien and Weber) and extends from the pulmonary ligament to the interlobar margin. Finally, analysis of the anterior basal bronchus (B^8) shows that it and not B^7 is the defective bronchus (vide infra).

The details of the distribution of B^7 are recorded in Table VIII. In 55 per cent of specimens (Item II: 1) it aerates the whole inferior portion of the anterior surface of the lobe, as measured along the inferior margin (Plate 3, No. 53). In a smaller group (20 per cent: Item II: 2) it supplies only the medial one-half to *two-thirds of the lower anterior surface (Plate 2, No. 58). In the* remaining 22 per cent in which B^7 is present (Items II: 3 and 4) it invades the costal surface, either by spreading of its branches (Plate 3, No. 55) or by virtue of accessory rami (Plate 4, No. 60).

From another standpoint, it also deserves an independent status—namely, its resectability. Not only is the bronchus available, being visible at the inferior margin of the hilum (Plate 3, No. 55) but in 25 per cent of specimens its medial border (at the pulmonary ligament) is marked by a fissure which extends well into the diaphragmatic surface (Plate 2, No. 56 and Plate 3, No. 55). In addition, there is usually a notch at that point.

Finally, mention should again be made of those specimens in which the left upper lobe is fused to the cardiac surface of the lower lobe. In some instances, B^7 may aerate this adherent laminar portion of the upper lobe (Plate 4, No. 54 and No. 60); in others, the latter is supplied by a lingular bronchus (Plate 2, No. 56).

THE ANTERIOR BASAL SEGMENTAL BRONCHUS (B^8)

The anterior basal segmental bronchus is the least constant of the basal bronchi of the left lower lobe and thus presents a marked contrast to its homologue of the right side; for in 27 per cent of specimens it is defective either in origin—that is, one of its two rami arises as an accessory branch of another bronchus—or it fails to reach the diaphragmatic surface.†

Typically (in 70 per cent of specimens), the anterior basal arises with the medial basal (B^7) through the medium of a short common trunk which may be seen at the lower end of the hilum arising high up on the anterolateral aspect of the basal trunk (Plate 2, No. 58). In another 13 per cent (Table IX, Item I: 2), it arises alone at the site of the common trunk (Fig. 7, No. 41). In the remaining 17 per cent either its basal ramus (B^8b) or its lateral ramus (B^8a) is absent as such, being represented by an accessory branch of another bronchus (Item I: 2, [2] and [3]). In general the accessory lateral rami arise from the subsuperiors, $BX^*(9)$ or B^* (Plate 1, No. 51), and the accessory basal rami take origin from either the medial or lateral basal bronchi, B^7 and B^9 (Plate 4, No. 54; Plate 3, No. 53). In addition, rami from adjacent bronchi may spread into the territory of B^8, crowding the latter, for example, out of the diaphragmatic surface (Plate 1, No. 52).

TABLE IX. THE ANTERIOR BASAL BRONCHUS (B^8)

I. Origin		
1. Arises from a short common trunk with B^7		70%
2. Atypical origin		30%
(1) B^8 arises alone from basal trunk in its usual place† (Fig. 5)	13%	
(2) B^8a only arises with B^7	8.3%	
BX^8b from basal trunk		
BX^8b from B^9 (Plate 3, No. 53)		
BX^8b from B^7 (Plate 4)		
(3) B^8b only arises with B^7	8.3%	
BX^8a from $BX^*(9)$		
BX^8a from B^* (Plate 1, No. 51)		
II. Distribution		
1. Reaches diaphragmatic surface (Plate 2, No. 56)		83%
2. Fails to reach diaphragmatic surface (Plate 3, No. 55)		17%

†In one specimen B^8 arose in conjunction with B^9.

The normal distribution of B^8 on the anterior surface is best illustrated by Plate 2, No. 56. The lateral ramus (B^8a) supplies the upper half (upper third to two-thirds) of that part of the anterior interlobar surface which lies below the superior segment, together with the adjacent lateral costal surface (Plate 2, No. 58). Since the zone between B^6 and B^8b is at the same level as the interpolated subsuperior segment, the subsuperiors (B^*, and BX^* from B^9)

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†In 17 per cent, it is defective in number of branches (Table IX, Item I:2), and in 17 per cent it fails to reach the base of the lung (Item II:2). Since seven of the 34 per cent are atypical in both respects, there remains a total of 27 per cent defective segments.

frequently send accessory branches to the B^8a zone (Fig. 6, No. 23) and sometimes take it over completely (Plate 1, No. 51).

The basal ramus (B^8b) typically supplies the lower lateral half (lower third to two-thirds) of the interlobar surface, that is, lateral to a line drawn from the inferior margin of the hilum to the lateral inferior angle of the lobe (Plate 2, No. 56). In only 27 per cent of specimens does it invade the area medial to this line (Plate 2, No. 58). Its typical diaphragmatic distribution is shown in Plate 2, No. 56. As noted previously, it fails to reach the diaphragmatic surface in 17 per cent of specimens.

Resection of this segment would seem to be feasible anatomically, on account of the high origin of B^8 and the accessibility of the segment, but it would seem necessary to anticipate the numerous variations described here.

THE LATERAL BASAL SEGMENTAL BRONCHUS (B^9)

Below the origin of B^{7+8} the stem bronchus continues only a short distance (Fig. 2, *B*) before giving off the lateral segmental bronchus (B^9). On the left side, B^9 and B^{10} lie in virtually the same plane (80 per cent of specimens; Table X, I: 1) but the keel separating the two is so tilted that the orifice of B^9 lies slightly in front of B^{10}.

TABLE X. ORIGIN OF THE LATERAL BASAL BRONCHUS (B^9)

I. Arises From Basal Trunk in Common With B^{10}		90%
1. B^9 and B^{10} lie in same plane (Plate 4)	80%	
2. B^9 lies in a plane anterior to B^{10} (Plate 1, No. 52)	10%	
II. Absent as Such (i.e. displaced)		10%
1. Represented by an accessory ramus of B^7 (Fig. 7, No. 4)	7%	
2. Represented by an accessory ramus of B^{10}a 3. Represented by rami of B^7, B^8, and B^{10}	3%	

Usually within a distance of 12 mm. below the keel, a prevailingly posterolateral ramus is given off in 67 per cent of specimens. This contributes to the subsuperior zone and therefore has already been described as an accessory subsuperior—BX*(9). It is the homologue of B^9a, the lateral ramus of B^9 on the right side. However, on that side B^9 rarely contributes to the subsuperior zone.

Below this ramus the main stem of B^9 continues toward the diaphragmatic surface supplying the posterolateral sector of both the costal and the diaphragmatic surfaces (Plate 2).

In 10 per cent of specimens, B^9 is absent as such, being represented by displaced rami arising as accessory branches of adjacent bronchi. In this respect it resembles the corresponding bronchus on the right side which is absent in 8 per cent of specimens. In 7 per cent it takes origin from B^7 (see BX^9 in Fig. 7, No. 4). In another 3 per cent it arises from either B^{10}a or by a multiple origin from B^7, B^8, and B^{10}. In contrast to this, the accessory BX^9 of the right lower lobe always arises from B^8. In both lobes, however, the contributing bronchi are on the lateral side. As on the right, B^9 is considered to be too deeply placed to be readily resected.

THE POSTERIOR BASAL SEGMENTAL BRONCHUS (B^{10})

The posterior basal bronchus is the largest of the basal bronchi of the lower lobe and is considered by some embryologists to be a continuation of the paravertebral branch in 30 per cent of specimens. Both B^9 and B^{10} originate too deeply to be considered readily resectable as individual units.

REFERENCES

1. Adams, R., and Davenport, L.: The Technic of Bronchography and a System of Bronchial Nomenclature, J. A. M. A. 118: 111-116, 1942.
2. Aeby, Ch.: Der Bronchialbaum der Säugethiere und des Menschen, Leipzig, 1880.
3. Appleton, A. B.: Segments and Blood-vessels of the Lungs, Lancet 2: 592-594, 1944.
4. Boyden, E. A.: The Intrahilar and Related Segmental Anatomy of the Lung, Surgery 18: 706-731, 1945.
5. Brock, R. C.: Observations on the Anatomy of the Bronchial Tree, With Special Reference to the Surgery of Lung Abscess. Part IV. The Lower Lobes, Guy's Hosp. Rep. 92: 123-144, 1943.
6. Brock, R. C.: Observations on the Anatomy of the Bronchial Tree, etc., London, 1946, Oxford University Press.
7. Churchill, E. D., and Belsey, R.: Segmental Pneumonectomy in Bronchiectasis, Ann. Surg. 109: 481-499, 1939.
8. Davis, J. D.: Anatomic Variations of the Normal Tracheobronchial Tree, Arch. Otolaryng. 9: 404-413, 1929.
9. *De Pablo, V. E.: La architectura bronchopulmonar, Buenos Aires, 1940, A. Guidi* Buffarini. (Cited in Year Book, E. E. N. T., pp. 597-601, 1941.)
10. Dévé, F.: Les lobes surnuméraires du poumon, Bull. et mém. Soc. anat. 75: 341-367, 1900.
11. Ewart, William: The Bronchi and Pulmonary Blood-vessels, London, 1889, J. and A. Churchill, Ltd.
12. Foster-Carter, A. F.: The Anatomy of the Bronchial Tree, Brit. J. Tuberc. 36: 19, 1942.
13. Foster-Carter, A. F.: Bronchopulmonary Abnormalities, Brit. J. Tuberc. 40: 111-124, 1946.
14. Hagens, E. W.: Anatomy of the Tracheobronchial Tree From the Bronchoscopic Standpoint, Arch. Otolaryng. 38: 469-475, 1943.
15. Huizinga, E., and Behr, E.: On the Division of the Lung Segments, Acta radiol. 21: 314-325, 1940.
16. Jackson, Chevalier L., Jr., and Huber, J. F.: Correlated Applied Anatomy of the Bronchial Tree and Lungs With a System of Nomenclature, Dis. of Chest 9: 319-326, 1943.
17. Kent, E. M., and Blades, Brian: The Surgical Anatomy of the Pulmonary Lobes, J. THORACIC SURG. 12: 18-30, 1942.
18. Kent, E. M., and Blades, Brian: The Anatomic Approach to Pulmonary Resection, Ann. Surg. 116: 782-794, 1942.
19. Kramer, R., and Glass, A.: Bronchoscopic Localization of Lung Abscess, Ann. Otol., Rhin. & Laryng. 41: 1210-1220, 1932.
20. Lucien, M., and Weber, P.: La systematisation pulmonaire chez l'homme, Arch. d' anat, d'histol. et d'embryol. 21: 109-141, 1936.
21. Melnikoff, Alexander: Die chirurgische Anatomie des intrapulmonalen Gefässe und der Respirationswege, Arch. f. klin. Chir. 124: 460-510, 1922.
22. Neil, J. H., Gilmour, W., and Gwynne, F. J.: The Broncho-pulmonary Segments, M. J. Australia 2: 165-172, 1937.
23. Neil, J. H., Gilmour, W., and Gwynne, F. J.: The Bronchial Tree, Brit. M. J. 1: 495-498, 1939.
24. Nelson, H. P.: The Tracheo-bronchial Lymphatic Glands, J. Anat. 66: 228-241, 1932.
25. Nelson, H. P.: Postural Drainage of the Lungs, Brit. M. J. 2: 251-255, 1934.
26. Pierce, C. B., and Stocking, B. W.: Roentgenological Anatomy of the Chest, Am. Rev. Tuberc. 39: 516-527, 1939.
27. Pierret, R., Coulouma, P., Breton, A., and Devos, L.: Étude anatomique de la zone dorsale moyenne du poumon, Ann. d'anat. path. 15: 233-247, 1938.
28. Smith, Franklin R., and Boyden, Edward A.: An Analysis of Variations of the Segmental Bronchi of the Right Lower Lobe of Fifty Injected Lungs, J. THORACIC SURG. 18: 195-215, 1948.

ALVEOLAR CELL CARCINOMA OF THE LUNG (PULMONARY ADENOMATOSIS, JÁGZIEKTE?)

A Multicentric Tumor of Epithelial Origin

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IT IS customary to think of a carcinoma as being a local disease, at least of having originated in a small area. It is that conception, of course, which is responsible for the prevalence of surgical attack on the condition. That the conception is correct seems to be borne out by the frequent success in obtaining permanent cures by the surgical removal of the diseased part together with the extensions of the growth from its original site. Regarding primary carcinoma of the lung the generally accepted idea, based on evidence accumulated within recent years, is that this condition not only arises in a bronchus, and is therefore more properly called bronchiogenic carcinoma, but that also like other carcinomas it arises in *one spot or area*. There can be no doubt that this concept is true for the overwhelming majority of cases of primary carcinoma of the lung.

Yet a few case reports have appeared describing a type of tumor, resembling a carcinoma, which seems to have arisen in the cells lining the alveoli rather than in a bronchus. Moreover, this peculiar tumor seems to have a multicentric origin and thus differs from the common and well-recognized bronchiogenic carcinoma. In this respect it has some resemblance to the primary cancer of the lung in the mouse familiar to the geneticists. Also it resembles the interesting and supposedly virus disease of South African sheep, known as jagziekte.

Several interesting questions arise in connection with this condition. If it is a true carcinoma arising in the alveoli, then the controversy about whether or not the alveoli are lined with epithelium seems apparently to be settled in the affirmative. The similarity to jagziekte raises the question of a possible virus infection in man similar to that in the sheep. Finally the question of the best surgical treatment arises.

It is because of these various considerations that the following case is presented. A special reason for reporting it is that apparently it has the longest follow-up period of any case in which the patient has been subjected to surgical treatment. The result seems to indicate that a two-year period of freedom from a manifestation of symptoms after a lobectomy gives no assurance of complete eradication of the disease, as proposed by Osserman and Neuhof[26] from their experience with a somewhat similar case.

Due to the differences in opinion as to its origin, the particular type of lung tumor characterized by the presence of malignant cells lining the alveoli and maintaining for the most part the general alveolar structure of the pulmonary parenchyma (in the absence of any demonstrable primary lesion elsewhere in the bronchial tree) has been given almost as many different names as the number of authors who have described the lesion. Despite the number of reports in the

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literature now there is still no uniformity of opinion in accepting the tumor as originating either in epithelial or mesenchymal elements, or, indeed in fact, in agreeing that it represents a tumor having a multicentric origin.

It has seemed to us, however, that the preponderance of evidence available at present allows us to consider this particular malignant pulmonary lesion as multicentric in origin and derived from endodermal elements. Consequently, it is permissible to encourage the use of the term "alveolar cell carcinoma," implying as it does the presence of epithelial cells lining the alveoli, malignant changes in which are responsible for the production of the tumor under discussion, and we shall attempt to present evidence offering a basis for this opinion. If a single name can thus be utilized in designating this specific lesion, the recognition that it is a distinct entity will be further encouraged, and clinical, pathologic, and statistical knowledge of this lung tumor gathered on a more certain footing. Future inaccurate tabulation of alveolar cell carcinoma as a form of adenocarcinoma of the lung of bronchiogenic origin can also be prevented by this means.

The historical data, incidence, signs and symptoms, and pathology were fully discussed recently by Ikeda[15] and it is not proposed to enlarge upon these phases of the subject. In brief, the tumor has been reported to occur in two forms, a nodular variety and a diffuse type in which confluence of the tumorous areas suggests a pneumonic picture in the gross. The lesions may be restricted to one lobe of a single lung or involve all lobes of both lungs simultaneously, and they occur within the lung parenchyma or appear on the pleural surface. On gross examination the nodules are commonly discrete with good definition from the surrounding tissue, but they may be irregular in outline or coalesce, this coalescence probably representing the basis for the diffuse form of the disease. The bronchi are not involved except as a result of direct invasion by one of the nodular areas, but metastases do take place to the regional lymph nodes, and occasionally to distant organs. The presence of the tumor in the vicinity of a bronchus may cause atelectatic changes and later inflammatory processes in the adjacent and peripherally situated parenchyma.

Microscopically, the tumor is easily recognized by its characteristic morphology, the malignant cells lining the alveoli, and the general structure of the parenchyma being maintained in most areas. The individual cells tend to be polygonal in shape with rather dark-staining, abundant acidophilic cytoplasm and may occur in multiple layers or in papillary projections within the alveoli, which are often completely filled by these formations of malignant cells. The nuclei are somewhat irregular, often hyperchromatic, and mitoses may be seen in keeping with the obvious neoplastic nature of the cells. An outstanding feature is the general lack of invasion of the supporting framework of the lungs, although occasionally a lymphatic vessel may be seen filled with malignant cells (as might be expected from the occurrence of lymph gland metastases) and in a few of the more malignant cases, the cells are found growing wildly in masses and cords among a loose fibrous tissue stroma. The fundamental feature in the recognition of the tumor is, of course, the very definite reproduction of alveolar structure. It is customary to find many frankly malignant areas that are completely separated as far as gross and histologic evidence is concerned, and occasionally other discrete areas are discovered in which single alveoli may show early hyperplasia of the lining cells of the alveolus, suggesting the beginning of still another focus of the tumor.

In the discussion to follow, this tumor is considered under two headings in accordance with the conflicting views held concerning its origin, (a) the multicentric nature of alveolar cell carcinoma of the lung, and (b) the epithelial origin of alveolar cell carcinoma of the lung.

THE MULTICENTRIC NATURE OF ALVEOLAR CELL CARCINOMA OF THE LUNG

Multiple primary malignancies are no longer the rarity that they were once considered to be, but it is still difficult to accept all the cases reported as actual examples of this condition for the criteria followed in assessing the cases are not always clear. However, the following studies, listed in Table I, seem well substantiated and the figures are included to illustrate the incidence of multiple primary malignancies generally without specific reference to the lung.

TABLE I

	NUMBER OF AUTOPSIES IN MALIGNANT DISEASE	CASES OF MULTIPLE PRIMARY MALIGNANCY	PERCENTAGE OF MULTIPLE MALIGNANCY
Owen, 1921	3,000	143	4.8
Orr, 1930			
(1) Personal cases	1,046	8	0.77
(2) Collected data	9,107	76	0.83
Hanlon, 1931	710	18	2.5
Warren and Gates, 1932	1,078	–	5.7
Schreiner and Wehr, 1934	11,212	307	2.7

The skin and intestinal tract are most commonly affected, with the female breasts and genital organs of both sexes involved with greatest frequency in paired structures. The rarity with which the lung is affected is illustrated in a recent study by Slaughter[20] of 1,868 collected cases of multiple primary malignancy in which he found 749 instances (40 per cent) in the same organs or systems, but not a single case in the lung, and 269 cases (14.4 per cent) in paired organs with only 3 reports of lung involvement. In addition, carcinoma of the lung occurred relatively uncommonly also in association with primary carcinomas affecting organs of other systems, there being in this series only 34 reports of such an association, representing an incidence of only 1.8 per cent as compared to 7 per cent for the stomach; 6 per cent for the prostate, and 4 per cent for the kidney.

Billroth's[6] original view (expressed in 1889) that three conditions must be satisfied before one can consider such lesions as examples of true multiple primary malignancy is now universally considered too exacting. To rule out lymphogenous and hematogenous metastases, extension by continuity or contact, and implantation or transplantation, he suggested that: (a) Each carcinoma must have a different histologic structure, (b) the histogenesis of each carcinoma from a different parent epithelium must be proved, and (c) each carcinoma must form its own metastases.

However, in certain types of multiple carcinomas, generally accepted as primary in origin, these conditions are certainly not fulfilled as, for example, in the case of the occurrence in multiple form of basal cell carcinoma of the skin which rarely metastasizes; for this reason Goetze[11] suggested the necessary criteria might be the following: (a) The macroscopic and microscopic appearance of the tumors must be that of the usual carcinomas of the organs involved, (b) exclusion of metastases must be certain, and (c) diagnosis may be confirmed by the character of the metastases in each case.

If one now accepts on this basis that such lesions as multiple skin carcinomas and multiple malignant polypi of the colon are true multiple primary malignancies, it would seem possible to accept multiple areas of malignancy in the lung as representing multicentric neoplasia, provided that it was possible to satisfy, by meticulous pathologic examination, conditions such as those to be outlined here, which were originally described by Cassili and White[7] in deciding that a case which they reported was in fact an example of multiple lung tumors arising independently from the alveolar lining cells.

1. No primary tumor could be found elsewhere in the body.
2. No primary tumor could be demonstrated in the bronchial tree. In this connection Weller[33] has stated that one must always search until the primary lesion is actually found, because he feels that all such multiple lesions are the result of lymphatic spread.
3. The tumor must be multicentric with areas of uninvolved parenchyma separating the malignant nodules.
4. The neoplastic cellular process must be confined to the alveolar sacs.
5. The interstitial framework of the lungs, except for the lymphatic vessels, must be generally free of the process.
6. The anatomy and histology of the nodules must be unlike any other primary lung process.
   (The fact that all lobes of the lungs were affected in their case seems of relatively little importance.)

Ever since Müller[21] divided the cases in which multiple primary malignancy was present into three groups (1) involving the same system (for example, skin and intestinal tract), (2) involving symmetrical paired organs (for example, breasts, ovary, testis, kidney, lung) and (3) involving distant organs of separate systems, it has been most difficult to satisfy the necessary criteria in the second group (including as it does the breast and genital organs); and it has also been customary to exclude from consideration (as do Warren and Gates[32]) cases of malignancy which is frequently multicentric in origin affecting a single visceral organ, such as carcinoma of the liver, although there seems little doubt that the separate lesions in this case arise independently. As a result of this latter exclusion, similar lesions of the lungs, such as those under consideration in this paper, have also commonly not been included in studies of multiple primary malignancy.

Although multiple lesions of the skin and those occurring in widely separated colonic polypi are now generally regarded as distinct primary changes, it is more difficult to rule out a metastatic basis in the case of paired organs such as the breast and the ovary, where multiple malignancies are next most commonly seen. As mentioned previously, reports in the literature venturing to call these lesions primary in type are often open to criticism. In fact Warren and Gates[32] also exclude most of these cases from their survey.

It is perhaps more difficult still to be certain that multiple lesions in a single lung can be considered to have arisen independently when spread may have occurred along alveolar walls, by the readily available vascular or lymphatic channels or by the intraluminal dissemination of cells with the air motion of ordinary or forced respiration. Nonetheless, sufficient reports have now appeared in which the histologic features are essentially the same regardless of the fact that the change may appear in discrete and widely separated areas or show a tendency to become confluent that it seems unlikely that spread by any of these means could have been responsible, particularly when the conditions outlined according to Casilli and White[7] are satisfied.

The observation that the experimentally produced lesions of alveolar hyperplasia, adenomatosis, and carcinomatosis to be mentioned later are commonly multiple in occurrence and that many of these changes appear simultaneously lends further credence to the view that similar changes occurring spontaneously in the human being are multicentric. In addition, Ikeda[15] stressed the point that in one of the cases he reported each of the nodules actually represented a well-developed intra-alveolar papilloma with a definite central fibrous core and he felt that this further observation also favored the theory of multicentric origin of the tumor.

In summary, then, it becomes apparent that this specific entity which has probably often been labeled an adenocarcinoma in the past is being reported with increasing frequency (for example, Adler[1] 20 cases in 1912, Neuberger and Geever[22] 25 cases in 1942, Ikeda[15] 4 cases in 1945) as its distinctive histologic appearance is accepted, and the typically multiple arrangement of neoplastic areas coupled with the failure to demonstrate a hidden primary tumor permit general acceptance of the view that it has a multicentric origin.

THE EPITHELIAL ORIGIN OF ALVEOLAR CELL CARCINOMA OF THE LUNG

Just as there has been hesitation in accepting the multicentric origin of pulmonary tumors having this distinctive histologic appearance, so also has there been lack of general agreement concerning the presence or absence of a layer of cells lining the alveoli from which this neoplasm might arise. Furthermore, disagreement has been apparent in deciding whether this layer of cells, if it is actually present, develops from endodermal or mesenchymal elements and, consequently, whether it is proper to name the tumor a carcinoma at all.

It is undoubtedly difficult, if not impossible, to demonstrate a lining layer of cells in the alveoli of normal lung tissue, but as Miller[20] points out in his monograph, it is often necessary for the pathologist to turn to normal tissues when in doubt as to the correct designation of a certain cell or group of cells, and in a similar manner the normal histologist may be obliged to inspect pathologic material in order to obtain better insight into the structures under observation. In the case of the lung, he has shown beautifully the presence of a continuous layer of lining cells in the alveoli when they are rendered visible by being separated from the underlying framework of connective tissue and vessels by (a) the pouring out of a serous exudate behind them in a pneumonia or (b) the mechanical edema of mitral stenosis with insufficiency of the valve. In these cases the lining appears as a layer of flattened epithelium in a continuous sheet, the nucleus bulging out in the thinned-out portion of the cell.

Miller[20] also pointed out that the presence of "pores" in the alveolar walls may be explained on the basis of pathologic changes occurring when the epithelium is pushed off in this manner and that they are not necessarily normally present. When the epithelium is pushed off from diametrically opposed sides of an alveolar wall, the serum poured out from the capillaries then finds an exit into adjoining alveoli and with the conversion of fibrinogen into fibrin the characteristic strands of fibrin passing through the alveolar wall are formed (see Macklin).[17] In these cases epithelial cells may be seen attached to the strands of fibrin as they leave the alveolar wall. Macklin[18] demonstrated residual epithelial cells on the pulmonary alveolar walls in various mammals, and he believes it is possible that primary carcinoma of the lung can originate from these cells in man.

Nonetheless, it has been repeatedly observed that cells may be seen lining the alveoli in certain diseased conditions such as chronic passive congestion, lipoid pneumonia, chronic interstitial pneumonia, and other chronic inflammatory processes such as empyema, abscess, bronchiectasis, and tuberculosis. The process appears to be one of hyperplasia of the lining cells and has been termed "epithelization" of the alveoli.

Similar changes which may progress to adenomatous formations and frank malignancy can be produced experimentally by the use of certain chemical carcinogenic compounds. Andervont[2] was able to show for the first time in the lung that carcinogens do not act only locally when he produced primary lung tumors in a certain pure strain of mice by the subcutaneous injection of dibenzanthracene, usually without the occurrence of subcutaneous tumors. Although this strain of mice had a high incidence of spontaneous lung tumors, the induced growth appeared much earlier and it was postulated that following absorption of the carcinogen from the subcutaneous tissue it was carried to the lung where it accelerated the normally occurring carcinogenesis. Lung tumors could, of course, also be produced by the implantation of dibenzanthracene directly into the lungs of this mouse strain.

It is interesting to note that Andervont[3] also bred male and female mice of high pulmonary tumor strain to females and males, respectively, of low pulmonary tumor strain, where all attempts at the induction of lung tumors by dibenzanthracene had failed, and following this females of the first hybrid generation were then mated to their brothers to produce the second hybrid generation. The presence of tumors in a high percentage of both the first (90 per cent) and the second (75 per cent) hybrid generation shows that the susceptibility of the lung to tumor formation induced by the subcutaneous injection of a lard-dibenzanthracene solution is inherited in a dominant manner and is clearly specific for that particular organ.

Multiple adenomatous tumors originating along the alveolar walls have been produced experimentally in mice by Grady and Stewart,[12] and spontaneous multiple tumors of the same type, also in mice, have been observed by Slye, Holmes, and Wells.[30] These adenomatous lesions resemble those described by Cowdry[8] in

South African sheep, a disease known as jagziekte and probably caused by a virus, the counterpart of which has been reported in human beings under the name of adenomatosis by Bell.[5]

We then have definite cellular changes occurring in the alveolar walls in response to many of the factors that have been shown by those working in cancer research to be potentially responsible for tumor formation in general. The factors mentioned have been (a) chronic irritation (chronic inflammations in human beings), (b) chemical carcinogenic compounds (in mice), (c) heredity (in mice), (d) tissue susceptibility (in mice), and finally (e) viruses (in sheep).

Surely, if such responses (hyperplasia or "epithelization" adenomatosis and malignant degeneration) can be regularly induced in the alveolar walls by such varying factors, it would seem that the presence of a cellular lining of the alveoli can no longer be denied, particularly in view of Miller's[20] masterful demonstration of its existence.

However, even if this reasoning is accepted, the question concerning the exact developmental nature of a lesion arising from these cells has still not been answered, for we have yet to decide whether they are of epithelial origin or have a mesenchymal background. No definite answer to this problem seems possible at the present but several factors are highly suggestive.

It is generally accepted by embryologists that the lung develops as a bud of endoderm from the foregut, which branches out into the surrounding mesenchyme as the lungs project into the thoracic celom. On this basis it would seem reasonable to expect that the sacculations (or alveoli) at the end of the branching tree would retain a layer of cells derived from the endodermal bud from which they developed. However, as Barnard and Day[4] pointed out, it has been noted that this cuboidal lining which is admittedly present in early embryonic life seems to disappear from about the fifth month onward and has not been seen to reappear at a later date. Quite possibly in view of Miller's[20] demonstration that a lining does exist, restudy of this problem with more modern techniques, as for example an artificial duplication of the increased venous pressure found in mitral stenosis, might show a similar lining of flattened cells that was not apparent before.

Those who believe that this lining layer does actually disappear theorize that the changes of hyperplasia, adenomatosis, or frank carcinomatosis, as described previously, occur as a result either of hyperplasia of the so-called "septal cells" (Maximow and Bloom)[19] which have a perivascular distribution and are probably mesenchymal in origin, or of extension into the alveoli of cells lining the bronchioles, the epithelial origin of which is uniformly accepted. In the first instance these mesenchymal septal cells may, as Neuberger[23] suggested, gradually form a continuous lining which becomes clearly demarcated from the adjacent tissues, but the absence of reticulum fibrils and the cellular appearance so closely resembling the usual adenomas or carcinomas make this theory appear improbable. It is only fitting to point out, however, that this latter objection is overcome if one accepts the views of Oppenheimer[24] (quoted by Neuberger and Geever) who does not believe that germ layers are specific and believes them capable of undergoing transformation from one type to another under different environmental conditions.

In supporting the second theory Herbut[14] favored the origin of the alveolar cells from the basal cells of the bronchioles since the fact that there is a continuation of these basal cells into the alveolar lining in some cases of bronchiectasis shows that such invasion is possible. Sweany[31] and Jaffe[16] also believe that these basal cells are multipotential and can develop into any type of cell in the bronchial tree including the so-called "alveolar cell," but actually in the literature there does not seem to be any irrefutable histologic evidence that extension of these cells has occurred into the alveoli in the lesions found in this particular type of pulmonary neoplasm.

In this regard Frissel and Knox[10] felt that the alveolar pattern of cellular arrangement merely represents an attempt on the part of the tumor cells to maintain proximity to the available vascular supply in the walls of air sacs and on this basis they felt justified in classifying the lesion as an adenocarcinoma of bronchiogenic origin.

Although it is impossible with our present state of proved knowledge to discard these other theories completely, we believe that there is a sufficient bulk of evidence favoring the presence of a definite cellular alveolar lining to accept its presence and also to consider the cells to be of epithelial rather than mesenchymal origin. Therefore, the term "alveolar cell carcinoma" would appear to be the one most suitable for the future designation of this specific pulmonary neoplasm.

CASE REPORT

The patient, E. L. W., a 35-year-old used car dealer, was admitted to Barnes Hospital on June 1, 1943, at which time he stated that he had suffered from a chronic cough for the past eight to twelve months, which had become productive in the six months prior to admission. At this time he was coughing up approximately one-half cup of foul-smelling, greenish yellow sputum each day, and although there had been no associated pain, voice changes, general weakness, or weight loss, he stated that he had noted a small amount of blood streaking of the sputum ten days before admission. This was the only occasion on which hemoptysis had been present.

There had been some dyspnea on exertion, associated with palpitation and vertigo, and these "dizzy spells" had become sufficiently severe that the patient had consulted a physician concerning them about six months before he was admitted and had been treated for "heart trouble" and "allergy" without any improvement. One month before admission he had been seen by a chest specialist who ordered a chest plate and subsequently referred the patient directly to a hospital.

The past history apart from some mild chronic sinusitis of many years' standing and a "touch of dropsy" did not appear to be significant, nor did the family history or the general functional inquiry. He did not smoke.

Physical examination at the time of admission revealed a few large moist râles at the lung bases posteriorly, with some questionable diminution in the audibility of the breath sounds over the right lung field. The temperature, pulse, respiration, blood pressure, and laboratory findings were within normal limits and the sputum was negative for tubercle bacilli or fungi. There were no other significant findings on physical examination.

A flat plate of the chest showed an infiltrative process in the right lower lung field (Fig. 1) which was nonspecific, and a lipiodol bronchogram showed all the bronchi on the left side as well as those to the right upper and middle lobes to be normal. Only a portion of the right lower lobe bronchus was filled, although several flecks of opaque material were visualized overlying the large area of infiltration.

Diagnostic bronchoscopy was similarly of little help. The trachea contained a little pus but the carina was thin and normal in appearance and the only noteworthy finding in any of the bronchi visualized was a slight bulging in one of the medial divisions of the right lower lobe bronchus from which a biopsy was taken. The pathologic report on the specimen, however, showed no areas suspicious of malignancy and was labeled as chronic inflammation. The material consisted of a polypoid mass covered on all sides with epithelium that occasionally seemed to be undergoing squamous metaplasia. There was a core of fibrous tissue with many blood vessels and a considerable inflammatory process throughout although most of the cells were lymphocytes.

It was felt that an exploratory thoracotomy should be performed and this was done (by E. A. G.) on June 8, 1943.

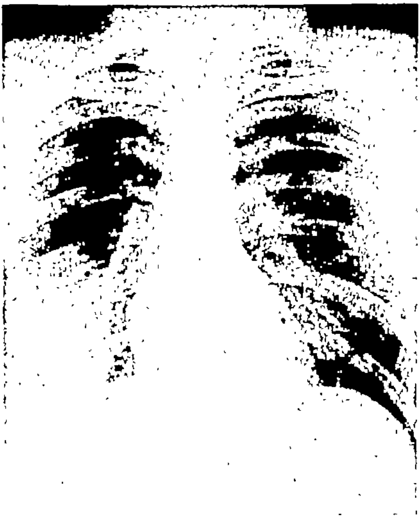

Fig. 1.—Roentgenogram of chest June 2, 1943, just prior to first operation. Homogeneous poorly delineated shadow in right lower chest. Upper lung field clear.

Operation.—On opening the chest there was no evidence of either pleural effusion or adhesions, but there was a mass of fairly firm tissue involving the greater portion of the right lower lobe and extending to the periphery where it caused a very marked dimpling of the visceral pleural somewhat suggesting carcinoma. However, it was felt that the consistency was not sufficiently firm to substantiate this suggestion and it was finally decided that the lesion was inflammatory in nature and consequently a lobectomy was performed. Ordinarily a frozen section would have been made at the time of operation, but the limited facilities for carrying it out because of war conditions made the procedure impossible.

A considerable amount of bloodstained fluid collected in the immediate postoperative period, and as closure had been effected without drainage, it was necessary to perform several thoracenteses to prevent a shift of the mediastinal structures. No evidence of infection appeared, however, and thereafter the postoperative course was uneventful and recovery satisfactory.

Pathologic Report.—The gross appearance was much as described previously with a depressed puckered looking area overlying the actual lesion, which on sectioning was found to comprise a well-encapsulated area of edematous and probably infected tissue. At one edge of this area was a small cavity containing some necrotic tissue, and surrounding this cavity the induration was sufficient to re-arouse the suspicion of carcinoma. It also suggested an organizing pneumonia (Fig. 2).

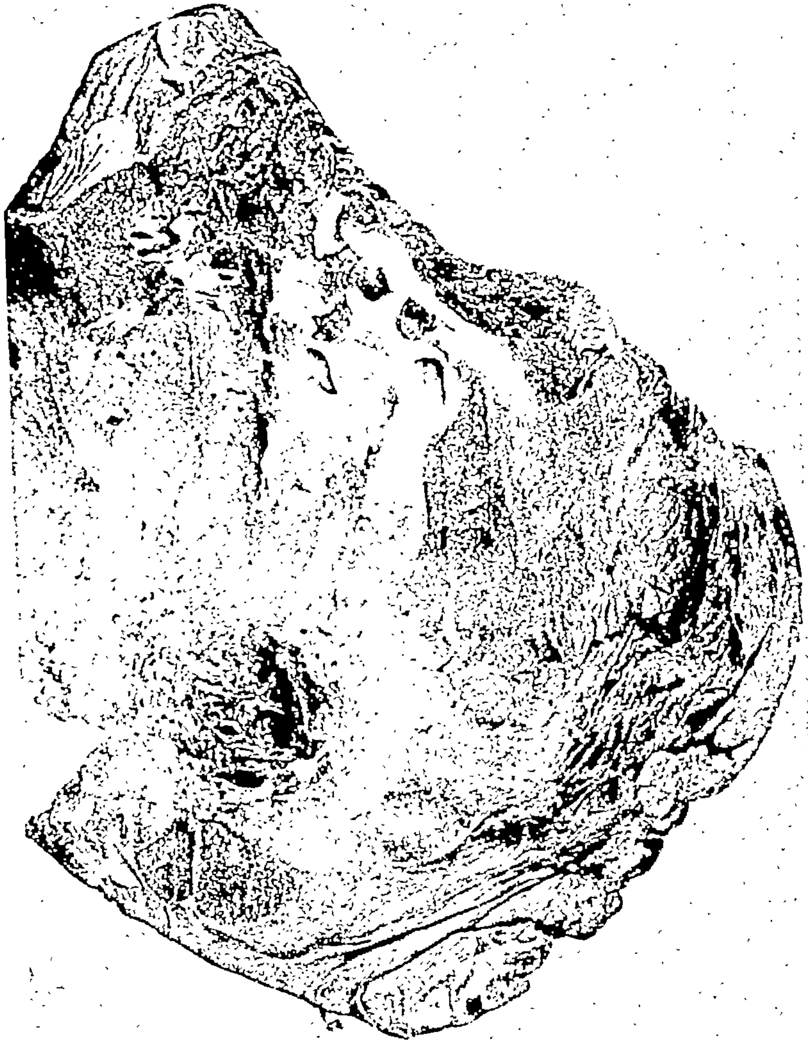

Fig. 2.—Gross specimen of right lower lobe removed June 8, 1943. Note gray-white area which suggests pneumonic process surrounding zone of cavitation. No lymph nodes involved.

Microscopically the tendency to reproduce the alveolar structure was by far the predominating feature of the lesion. Several well-defined areas of lung tissue showed almost complete replacement of the alveolar linings by hyperplastic epithelium comprised of polygonal cells having abundant acidophilic cytoplasm and dark-staining nuclei (Figs. 3 and 4). At the periphery of the lesion there were occasional isolated groups of alveoli in which the epithelium looked hyperplastic with increase in the cellularity, the cells tending to grow in small papillomatous formations projecting into the lumen of the alveoli (Fig. 5). In still other areas the tendency to the reproduction of alveolar structure was not seen, the cells growing wildly in clumps and cords in a loose fibrous tissue stroma. In these zones the malignant cells showed marked variation in size, shape, and staining reaction, and mitotic figures were fairly frequent. The remaining lung parenchyma showed a peculiar lobular distribution of edema and there was a marked chronic inflammatory reaction surrounding all the larger bronchi and bronchioles. There was no evidence either at operation or pathologically of involvement of the regional lymph nodes.

Although there was obviously a great deal of secondary infection and inflammation in the lobe it was recognized at the time by Dr. Nathan Womack that a carcinomatous process appeared to be arising simultaneously in several different regions. Also he called attention to the similarity of this case to jagziekte. Because of this fact and the lack of any evidence of regional metastases, it was decided unwise to consider completion of the pneumonectomy due to the probability that similar areas of involvement were present in the left lung. Perhaps this was an error in judgment in view of the subsequent history.

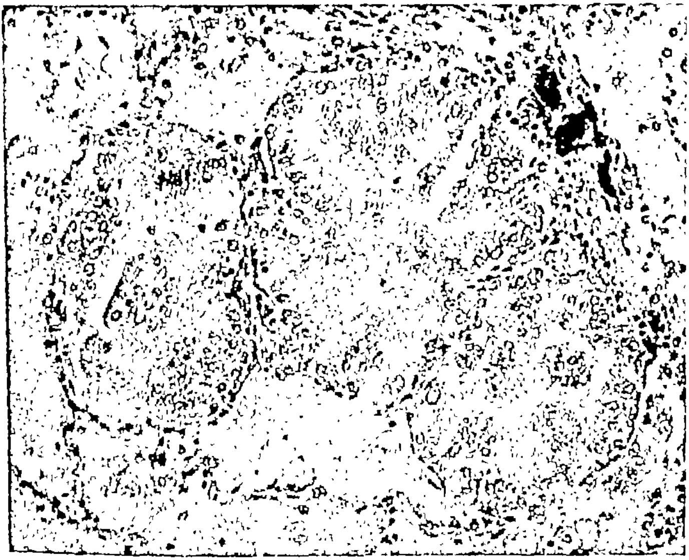

Fig. 5.—Characteristic nodule of well-differentiated tumor with preservation of alveolar pattern surrounded by normal lung parenchyma, first operation. (Photomicrograph ×420.)

Subsequent Course.—The patient made a satisfactory recovery and was well until the fall of 1946. He saw Dr. A. S. Ashmore of Wichita, Kan., in October, 1946, and complained at that time of a productive cough. An x-ray of the chest showed a lesion overlying the diaphragm measuring 2½ inches in diameter. He refused treatment at that time. He began to lose weight and developed pain in the right upper thorax and shoulder girdle region which interfered with the function of the right arm. On July 17, 1947, bronchoscopy was negative and the lipiodol examination was unsatisfactory, but the x-ray demonstrated a dense shadow obscuring the right lower lung field (Fig. 6). In December, 1947, exploration was done at Wichita by Dr. Ashmore and the remaining portion of the right lung resected. At the time of the exploration, tumor resembling "caviar" or "raspberry jelly" was seen growing over the chest wall where it had invaded over an area of 4 inches in diameter. The mediastinal lymph nodes were apparently negative. He made another uneventful recovery from this operation but because of the evidence of invasion of local tissues, he was given intensive postoperative irradiation therapy (7,000 r. through four portals). He was last seen in September, 1948. Bronchoscopy was negative and there were no tumor cells found in the smears from the bronchus. The opposite lung was clear to radiographic examination. He was in

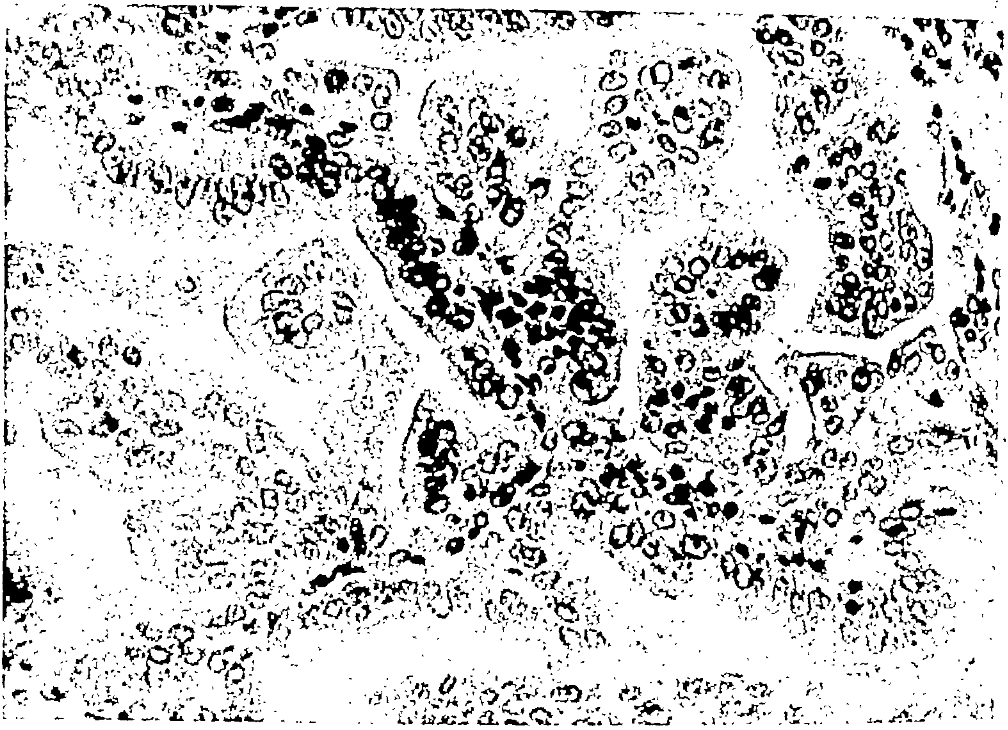

Fig. 4.—Detailed view of nodule of tumor demonstrating its well-differentiated character, first operation. (Photomicrograph ×420.)

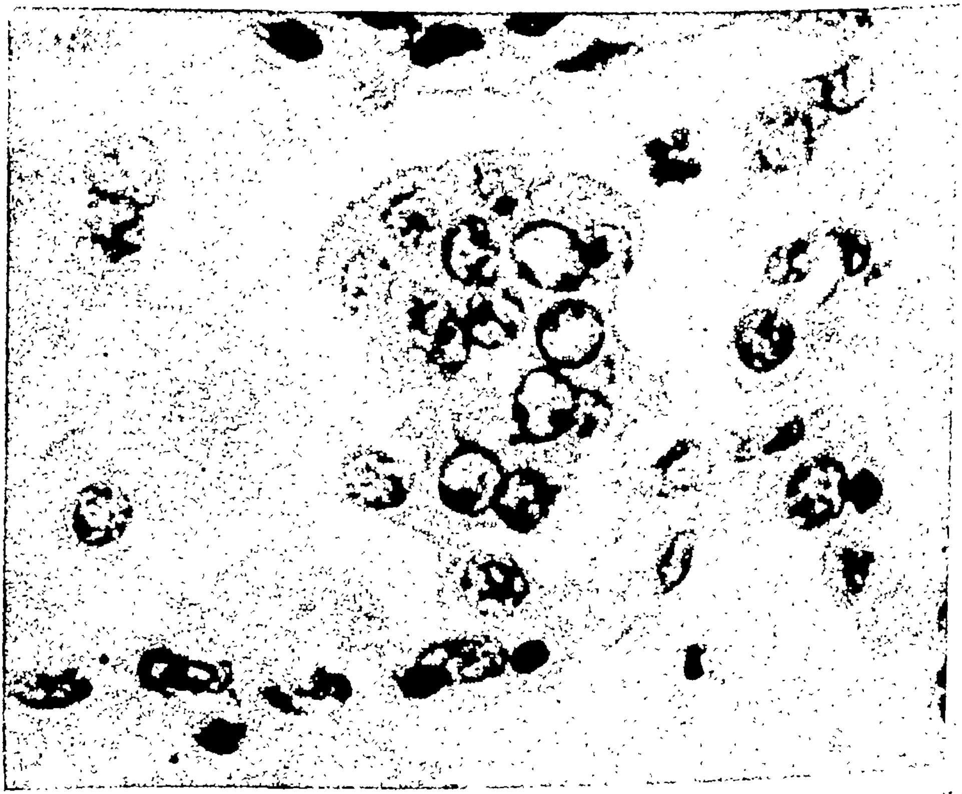

Fig. 5.—Cluster of tumor cells suggesting origin from alveolar epithelium, first operation. (Photomicrograph ×650.)

excellent clinical condition. The microscopic pattern of the tumor found at the second operation was very similar to that seen at the first operation (Fig. 7).*

DISCUSSION OF CASE

This patient has a known duration of his disease of at least six years. The initial lobectomy resulted in freedom from symptoms for about four years. At the time of the second operation the microscopic appearance of the tumor had not changed (Fig. 7). However, there was evidence of local invasion of the chest wall. The regional lymph nodes have remained free from disease. The opposite lung radiographically has shown no change but it is entirely possible that already in this lung there may be the early changes of hyperplasia (epithelization) or benign adenomatosis that are presumably of a precancerous nature.

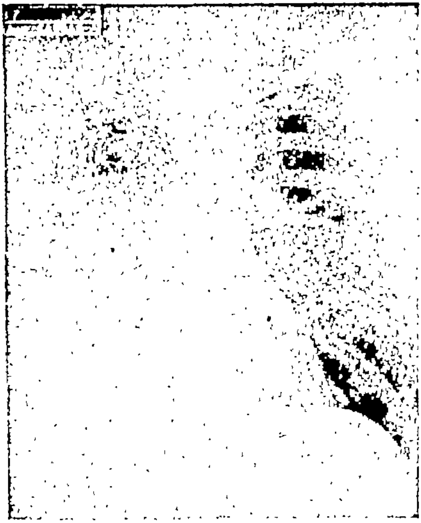

Fig. 6.—Roentgenogram of chest July 8, 1947, just prior to second operation. Dense shadow in right lower chest, high diaphragm, thickened pleura. Left lung clear.

The surgical treatment of this case has resulted at least in very worth-while palliation. The peculiar nature of the tumor, although probably malignant, and the absence of any known surgical experience with it prior to our operation in 1943, made the necessity of total pneumonectomy seem questionable at that time. Perhaps, however, further experience will show that the total removal of the lung is indicated as a palliative procedure in spite of the existing possibility of lesions in the other lung. This case would seem to suggest that. This patient is apparently the third treated surgically and the only one with a long follow-up (Drymalski[8] and Wood and Pierson[34]). Wood's patient had a right lower lobectomy for what was thought to be an inflammatory lesion. A roentgenogram six weeks after operation appeared to be clear of disease. The patient died six months later of carcinoma of the uterus. At post-mortem examination multiple foci of pulmonary adenomatosis were found in all remaining lobes. As Wood's case is very similar to the one reported here in both its clinical course and pathology, it lends further support to the concept of multiple foci of origin. His case also suggests that the case reported here may very well have other foci of tumor in the remaining left lung. Wood recognized the similarity of his case to jagziekte. No doubt the lobar distribution of the signs and symptoms of some of these cases is due to the strategic location of nodules of tumor close to a bronchus. This results in infection distal to the block and these changes give a clinical picture suggesting inflammation. If there is no surgical interference the patient dies of inflammatory complications. The case reported demonstrates the value of surgical resection in the presence of such localized inflammatory complications.

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*We are indebted to Dr. Ashmore for the history of the subsequent course, the x-ray film, and the microscopic sections from the second operation.

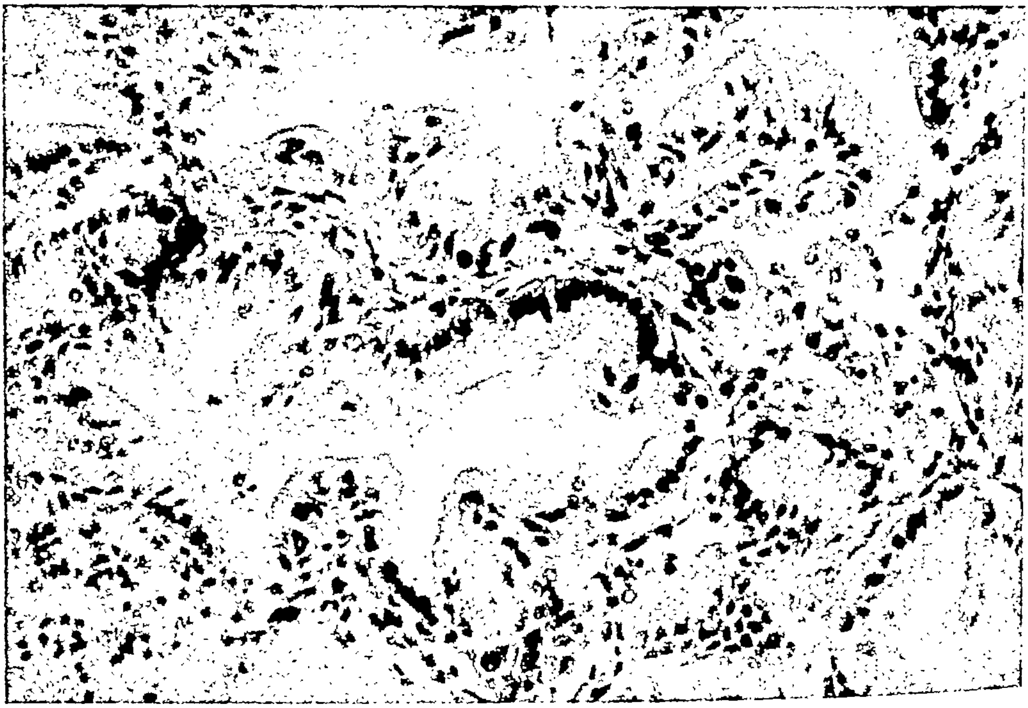

Fig. 7.—Persistent tumor in upper lobe. Note well-differentiated character and similarity to original tumor, second operation. (Photomicrograph ×60.)

SUMMARY

A brief review has been presented dealing with a specific type of pulmonary neoplasm which is characterized by a reproduction of the alveolar structure of the lung. The evidence is discussed which favors recognition of the multicentric nature of the lesion and seems to indicate that it may quite properly be called an "alveolar cell carcinoma." An illustrative typical case is reported which demonstrates the slow growth of the neoplasm and the palliation which may result from the removal of the diseased tissue, although the manifestations of the disease may reappear several years later in a different part of the lungs, as in this case. Also, attention is called to the similarity of this case to jagziekte, the South African disease of sheep.*

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*The pathology of this case has been reviewed by Dr. Lauren V. Ackerman of the Section of Surgical Pathology, Washington University School of Medicine, St. Louis, Mo.

REFERENCES

1. Adler, J.: Malignant Growths of Lung and Bronchi, New York, 1912, Longmans, Green & Co.
2. Andervont, H. B.: Studies Pertaining to the Appearance of Lung Tumors in Mice Injected With 1:2:5:6-Dibenzanthracene, Cancer Probl., Symposium, pp. 62-66, 1937.
3. Andervont, H. B.: Primary Tumors in Mice: Influence of Heredity Upon Lung Tumors Induced by the Subcutaneous Injection of a Lard Dibenzanthracene Solution, Pub. Health Rep. 52: 304, 1937.
4. Barnard, W. G., and Day, T. D.: The Development of the Terminal Air Passages of the Lung, J. Path. & Bact. 45: 67, 1937.
5. Bell, E. T.: Hyperplasia of the Pulmonary Alveolar Epithelium in Disease, Am. J. Path. 19: 201, 1943.
6. Billroth: Allgem. Chir. Path. & Ther., p. 908, 1889; quoted by Warthin, A. S.: Multiple Primary Carcinoma, J. A. M. A. 32: 963, 1899.
7. Casilli, A. R., and White, H. J.: Rare Forms of Primary Malignant Lung Tumors, Am. J. Clin. Path. 10: 623, 1940.
8. Cowdry, E. V.: Studies on the Etiology of Jagziekte. Origin of the Epithelial Proliferations and Subsequent Changes, J. Exper. Med. 42: 335, 1925.
9. Drymalski, G. W., Thompson, R. J., and Sweany, H. C.: Pulmonary Adenomatosis. A Report of Three Cases, Am. J. Path. 24: 1083, 1948.
10. Frissel, L. F., and Knox, L. C.: Primary Cancer of the Lung, Am. J. Cancer 30: 219, 1937.
11. Goetze, quoted by Hanlon, F. R.: Multiple Primary Carcinomata, Am. J. Cancer 15: 2001, 1931.
12. Grady, H. G., and Stewart, H. L.: Histogenesis of Induced Pulmonary Tumors in a Strain of Mice, Am. J. Path. 16: 417, 1940.
13. Hanlon, F. R.: Multiple Primary Carcinomata, Am. J. Cancer 15: 2001, 1931.
14. Herbut, P. A.: Bronchiolar Origin of "Alveolar Cell Tumor" of the Lung, Am. J. Path. 20: 911, 1944.
15. Ikeda, K.: Alveolar Cell Carcinoma of the Lung, Am. J. Clin. Path. 15: 50, 1945.
16. Jaffe, R. H.: The Primary Carcinoma of the Lung, J. Lab. & Clin. Med. 20: 1229, 1935.
17. Macklin, C. C.: Alveolar Pores and Their Significance in the Human Lung, Arch. Path. 21: 202, 1936.
18. Macklin, C. C.: Residual Epithelial Cells on the Pulmonary Alveolar Walls of Mammals, Tr. Roy. Soc. Canada 40: 93, 1946.
19. Maximow, A., and Bloom, W.: A Textbook of Histology, Ed. 2, Philadelphia and London, 1935, W. B. Saunders Company, p. 456.
20. Miller, W. S.: The Lung, Ed. 2, Springfield, Ill., 1947, Charles C Thomas, Publisher.
21. Müller, G. E.: Multiple Primary Carcinomas, Inaugural Dissertation, Tubingen.
22. Neuberger, K. T., and Geever, E. F.: Alveolar Cell Tumor of the Human Lung, Arch. Path. 33: 551, 1942.
23. Neuberger, K. T.: Primary Multiple Alveolar Cell Tumor of the Human Lung, J. THORACIC SURG. 10: 557, 1941.
24. Oppenheimer, J., quoted by Neuberger, K. T., and Geever, E. F.: Alveolar Cell Tumor of the Human Lung, Arch. Path. 33: 551, 1942.
25. Orr, J. W.: Multiple Malignant Neoplasms, J. Path. & Bact. 33: 283, 1930.
26. Osserman, K. E., and Neuhof, H.: Mucocellular Papillary Adenocarcinoma of the Lung and Lobectomy, J. THORACIC SURG. 15: 272, 1946.
27. Owen, L. J.: Multiple Malignant Neoplasms, J. A. M. A. 76: 1329, 1921.
28. Schreiner, B. F., and Wehr, W. H.: Multiple Primary Cancer as Observed at the State Institute for the Study of Malignant Disease, Am. J. Cancer 20: 418, 1934.
29. Slaughter, D. P.: Multiplicity of Origin of Malignant Tumors; a Collective Review, Internat. Abstr. Surg. 79: 89, 1944.
30. Slye, M., Holmes, H. F., and Wells, H. G.: The Primary Tumors of the Lungs in Mice, J. Med. Research 25: 417, 1914.
31. Sweany, H. C.: A So-called Alveolar Cell Carcinoma of the Lung, Arch. Path. 19: 203, 1935.
32. Warren, S., and Gates, O.: Multiple Primary Malignant Tumors. A Survey of the Literature and Statistical Study, Am. J. Cancer 16: 1358, 1932.
33. Weller, C. V.: The Pathology of Primary Carcinoma of the Lung, Arch. Path. 7: 478, 1929.
34. Wood, D. A., and Pierson, P. H.: Pulmonary Alveolar Adenomatosis in Man, Am. Rev. Tuberc. 51: 205, 1945.

ECTOPIA BRONCHI

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DEVELOPMENTAL abnormalities of the tracheobronchial tree and of the pulmonary parenchyma are rarely found in life or at necropsy. Even after careful clinical scrutiny one commonly confuses such abnormalities with other pulmonary diseases, or else arrives at a diagnostic impasse. We are principally interested here with ectopia of the bronchi to the left upper lobe and with the resultant varied parenchymal changes in the left lung.

EMBRYOLOGY

Arey[1] in discussing the embryology of the lung stated that in the 3 mm. human embryo the lung first appears as a groovelike evagination on the ventral surface of the esophagus. The enlarged caudad end of this evagination gives origin to two small lung buds. At a later stage, the predestined anlagen of the esophagus and trachea become separated by a constriction. This constriction is separated at the cephalic end by the larynx which is demonstrable at the end of the fifth week in the embryo. Hollow evaginations of the lung buds extend into the surrounding mesenchyme, enlarge rapidly, and branch to produce a treelike tubular system. The surrounding mesenchyme by the end of the seventh week gives rise to muscle fibers, cartilaginous rings, and probably to the lining cells of the alveoli.

Ekehorn[2] and Flint[3] related that the lower, blind end of the primordial trachea becomes fixed, divides, and then projects into each thorax (stem bronchi) where, by a process of arborization and downward growth, the bronchial tree is developed. Heiss[4] believed that a process of infolding and septum formation are the developmental mechanics responsible for the progressive differentiation of the lung. He rejected the term and conception of stem bronchi. For him, stem bronchi are the periphery of the lung from which the connecting and terminal structures of the lung parenchyma are formed by a continuous infolding.

Ferguson and Neuhauser[5] added that as a result of the sequence of embryologic events "complete absence of the lung, with no lung bud or main stem bronchus whatever, indicates a developmental defect which has occurred very early in fetal life."

Gruenfeld and Gray[6] speculated that developmental anomalies of the lung are caused by "phylogenetic newness of the organ" and by the "enormous growth it must undergo in the embryo before its functional form is achieved." They first identify the division of the left stem bronchus into its two main bronchi in the 7 mm. length human embryo. It is interesting that in their review of lung malformations there is not included an example of the type here presented.

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Schneider[7] classified aplastic lungs according to the presence or absence of a rudimentary bronchus or of an aplastic lung. He further differentiated such aplasia into high and low degrees depending on the absence in whole or in part of the bronchial or pulmonary element.

Jordan[8] in his detailed classification of pulmonary anomalies would include the case herein reported as "agenesis of bronchus—to a normal lobe."

Caffey[9] in describing the congenital defects associated with total aplasia of the lung included ". . . . diaphragmatic defects, cardiac and renal malformations, skeletal abnormalities, and absence of the vagus nerve." He considered that the high frequency of association of pulmonary aplasia with hemivertebra justifies considering the combination as a "syndrome." He presented a case showing bronchographic evidence of absence of the eparterial bronchus in association with an hemivertebra of the eleventh thoracic vertebra. Peeler and Phillips[10] cited the finding in a 2-month-old infant of a hypoplastic bronchus to the left upper lobe; however, there was no histologic examination. Cassinelli[11] and Nelson[12] each discussed a similar case which on microscopic examination was found to have a marked diminution in the number of cartilaginous rings. Morelli[13] discussed the possibility that an aberrant pulmonary artery might produce this latter aberration. He, too, cited a case in which the bronchus to the left upper lobe was small and lacking in cartilaginous rings and in total cartilage in the rings present. Diagnosis was made on his patient at 1 month of age, and substantiated at necropsy at 4 months of age. He indicted the aplasia of bronchus and bronchial cartilage as the agent precipitating the emphysema.

In concluding this review of the literature on the embryology of the trachea, bronchi, and lungs, we feel with Harris and Lewis[14] that knowledge of the comparative anatomy and embryology of the bronchial system has not kept pace with thoracic surgery. This lack of information is reflected in the difficult recognition of such lesions.

CASE REPORT

A white boy, aged 9 years, was admitted[*] April 23, 1947, to Children's Hospital, Akron, Ohio. The child's physical and mental growth and activities were not unusual until 1945, when for the first time he was noted to tire readily and to become dyspneic upon exertion. A physician made the diagnosis of dextracardia and cautioned the parents to limit the child's physical activities; as a result of this the child became acutely aware of his heart and selectively limited his activities to his own favorite sports. During the next two years his only complaint was of shortness of breath; there was no cough, expectoration, chest pain, or known evening hyperthermia.

Physical examination on admission revealed a thin, 9-year-old, intelligent, cooperative white male child in whom positive findings were limited to the thorax. The thoracic cage was asthenic in type with a widening of the intercostal spaces on the right and a narrowing and relative immobility of those on the left; there was a slight list of the left shoulder. The heart rate was 110 with a normal rhythm; the left border of cardiac dullness was retrosternal, the right was at the right nipple. On the left side there was increased resonance and diminished breath sounds and voice conduction. On the right side breath sounds were normal. There was a mild secondary anemia. Intermittent afternoon fever as high as 100.4°

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[*] On the medical service of Dr. Noah Miller.

Fig. 1.

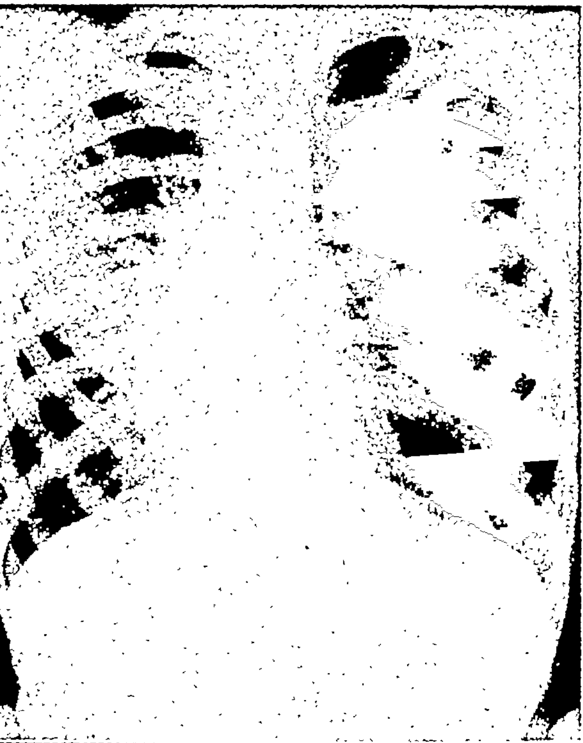
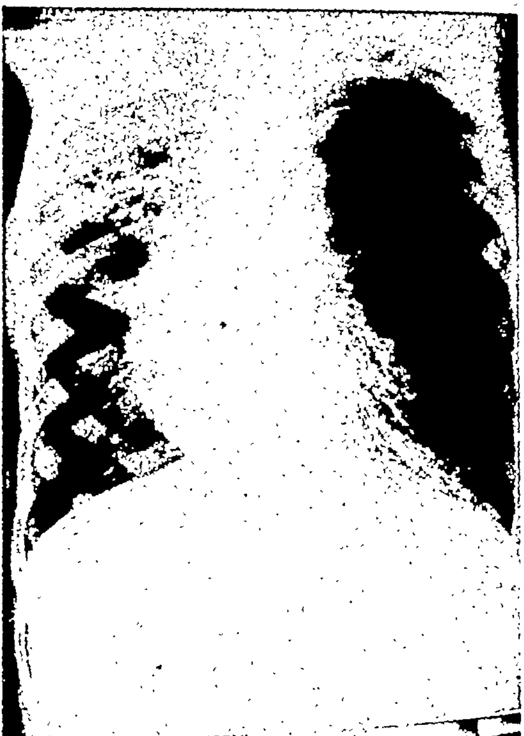


Fig. 2.



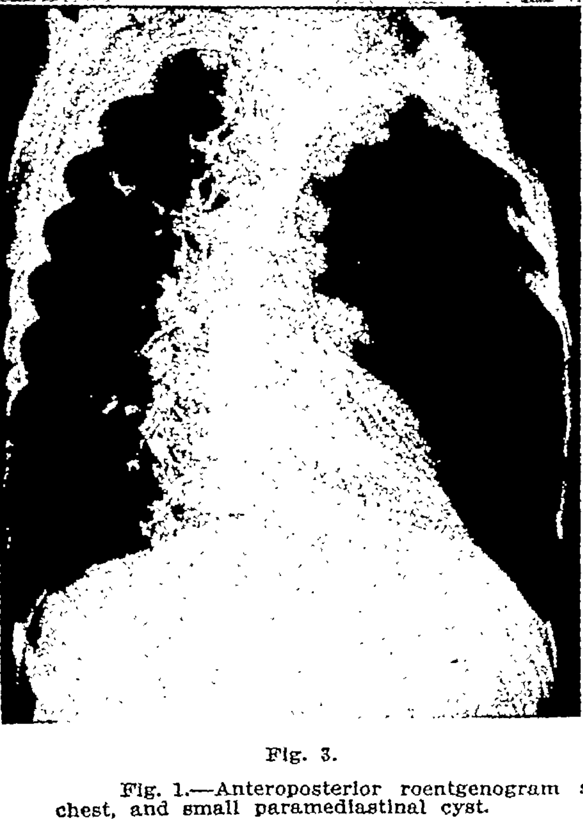


Fig. 3.

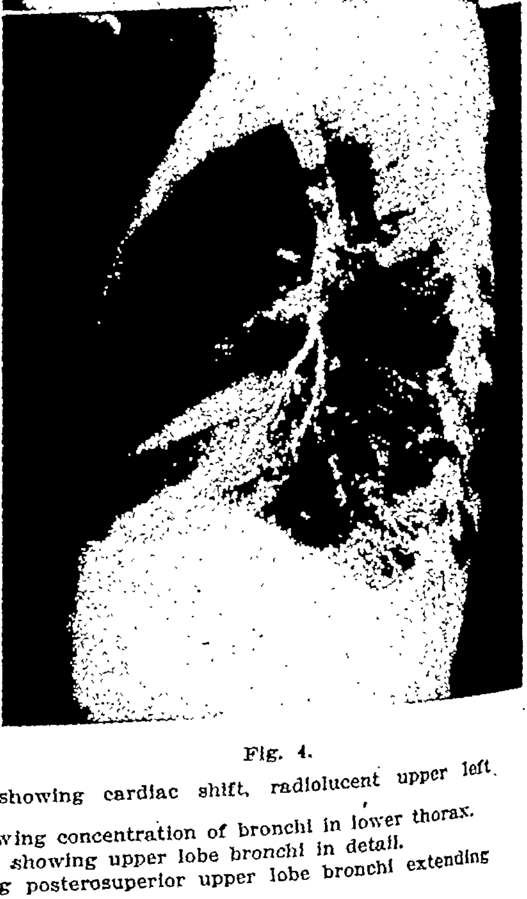


Fig. 4.

Fig. 1.—Anteroposterior roentgenogram showing cardiac shift, radiolucent upper left chest, and small paramediastinal cyst.

Fig. 2.—Anteroposterior bronchogram showing concentration of bronchi in lower thorax.

Fig. 3.—Left postero-oblique bronchogram showing upper lobe bronchi in detail.

Fig. 4.—Left lateral bronchogram showing posterosuperior upper lobe bronchi extending into emphysematous mass.

F. was noted. Intrathoracic pressure readings in the second left interspace were: on inhalation, plus 2 cm. water pressure, on exhalation, plus 6 cm. After aspiration of 200 c.c. of air the pressure readings were: on inhalation, minus 10 cm. water pressure, on exhalation, minus 4 cm. The patient coughed vigorously twice, and following this the readings returned to the pre-aspiration levels.

Anteroposterior x-ray view revealed (Fig. 1) a shift of the mediastinum to the right with a semblance of a dextracardia. A few fine pulmonary markings appeared to radiate from the left hilum into the superior and lateral aspect of the left lung area; these markings radiated from an area 3 cm. in diameter of increased density located just to the left of the hilus. A concentration of pulmonary markings in the lower fifth of the left thorax suggested a compression type of atelectasis. Bronchograms (Figs. 2, 3, and 4) revealed a concentration of an entire normal left bronchial tree in the atelectatic lower lung field, and a composite bronchodiagram, left lateral view (Fig. 5), identifies each bronchus according to the systems of Boyden[15] and Jackson and Huber.[16] In the anteroposterior (Fig. 2)

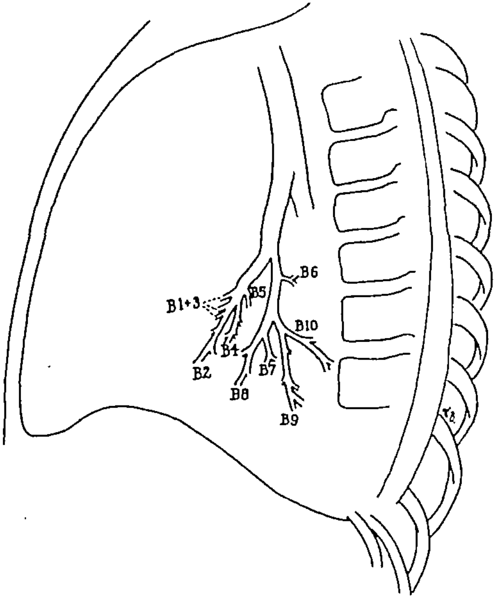


Fig. 5.—Composite bronchodiagram, left lateral, developed from Fig. 4, with identification of bronchi according to the system of Boyden,[15] and correlation (below) to the system of Jackson and Huber.[16]

UPPER LOBE

BOYDEN	JACKSON AND HUBER
B 1 plus 3	Apical-posterior
B 2	Anterior
B 4	Superior (lingular)
B 5	Inferior (lingular)
LOWER LOBE	
B 6	Superior
B 7 B 8	Anterior-medial basal
B 9	Lateral basal
B 10	Posterior basal

and left lateral (Fig. 4) views there are several fine branches extending cephalad from the first 2 cm. of the upper of the two stem branches of the left main bronchus. These left upper lobe branches are identified (Fig. 5) as Bronchi 1 and 3 by the system of Boyden[15] and Scannell[17] or the posterosuperior segmental bronchi by Jackson and Huber.[16] It was subsequently determined that these bronchi were the only sources of air into the emphysematous upper lobe. The normal complement of upper lobe bronchi readily can be identified in the left posterior oblique view (Fig. 3), and the two bronchi to the lingula are seen to advantage in the lateral view (Fig. 4) to arise as separate branches from the lobe bronchus.

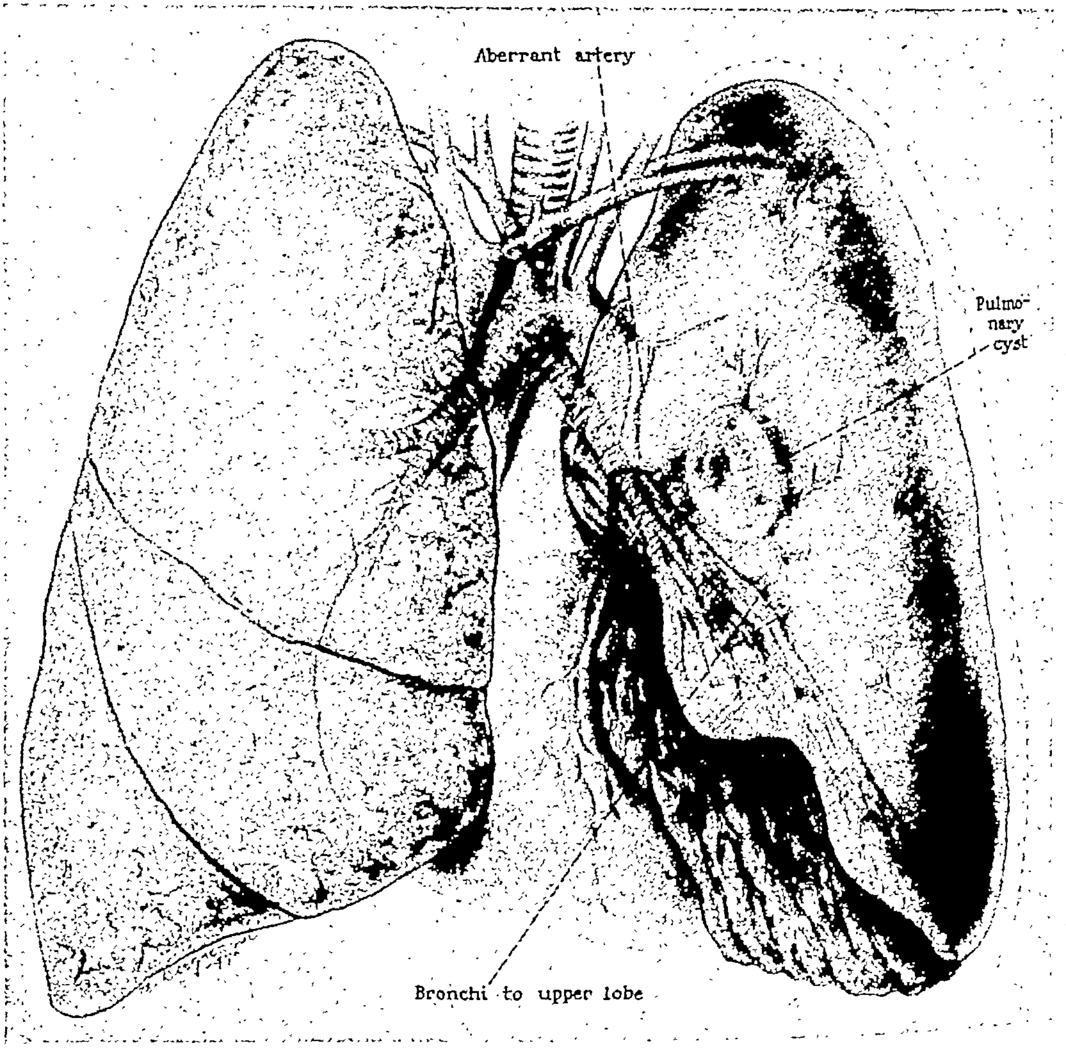


Fig. 6.—Illustrating atelectasis of left lower lobe and mediastinal shift secondary to emphysematous left upper lobe. Note aberrant artery and bronchi to upper lobe.

A diagnosis was made of pulmonary cyst of the left upper lobe with bronchopleural fistula and compression atelectasis of both lobes. It was felt that this cyst was sustained by a "ball-valve mechanism" in the communicating bronchi, and thoracotomy was undertaken in an effort to resect the cyst.

On May 21, 1947, under oral-intratracheal ether-oxygen anesthesia through a posterolateral incision with resection of the fifth rib and section of the fourth and sixth at the tubercle, the left thoracic cavity was opened. A minimal pneumothorax under slight positive pressure was found. The left upper lobe (Fig. 6) filled 80 per cent of the left thorax and obviously was exerting pressure on the atelectatic, dark, fibrotic lower lobe. Re-expansion of this lower lobe was impossible even with 20 cm. pressure exerted through the intratracheal tube. The upper lobe was pink and though spongy in consistency it still was tense and remained so even after the manipulation attendant on pneumonectomy. Increasing the intratracheal pressure increased slightly the tenseness of this upper lobe. The surface of the lower lobe had intercommunicating lobule markings strongly outlined with anthracotic pigment; however, these markings in the upper lobe were much more widely separated and were a bright pink in color. The heart and mediastinum appeared normal. In the hilus of the lung there were several soft lymph nodes measuring up to 1 cm. in diameter; the pulmonary artery and veins were normal in size and position. An aberrant artery 3 mm. in diameter originated from the aorta near the origin of the second left intercostal artery and was directed into the mediastinal aspect of the upper lobe. Total pneumonectomy was performed by individual suture-ligation silk technique, and the thorax was closed without drainage. Convalescence was uneventful, and the patient was discharged on the twelfth postoperative day; a chest roentgenogram taken twelve weeks later (Fig. 7) revealed a satisfactory position of the heart and mediastinum. The patient returned to school where he was found to have a much greater exercise tolerance; the "cardiac consciousness" was gone.

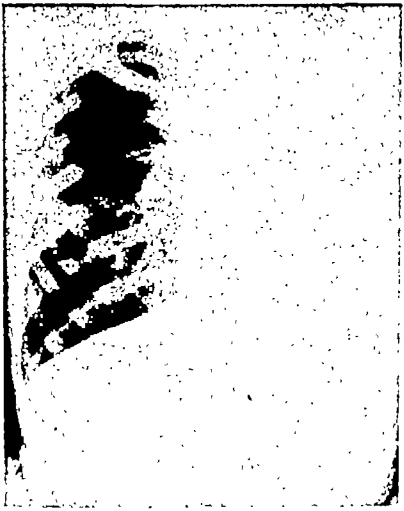


Fig. 7.—Anteroposterior roentgenogram taken twelve weeks postoperatively

Pathology.—The lung measured 6 by 12 by 17 cm.; the pink, emphysematous upper lobe was 5 by 12 by 13 cm. and had the form of a normal but greatly distended lobe. The pulmonary veins were normal in distribution. The pulmonary artery contributed several fibrinous branches to the upper lobe and then ramified throughout the lower lobe. The aberrant artery from the aorta branched soon after entering the upper lobe. The left stem bronchus entered only the lower lobe where it divided into two main trunks (Fig. 3). Just beyond this bifurcation the cephalad of these bronchi gave off three bronchi measuring about 2 mm. in diameter; these were identified as Bronchi 1 and 3 on the bronchodiagram. They extended across the interlobar fissure for about 2 cm. into the substance of the upper lobe where they terminated, patent, in the emphysematous tissue of the lobe. These were the only communications of the tracheobronchial tree with the upper lobe.

Cut section of the upper lobe revealed thin-walled emphysematous blebs throughout, 5 to 10 mm. in diameter. On microscopic examination (Fig. 8) the presence of such tissue was confirmed, and a diminished number of terminal bronchi were seen. Except for the previously described bronchi entering the lobe from the lower lobe there were seen but four or five bronchi, 2 to 3 mm. in diameter, and these radiated into the periphery of the lobe from a hilar cyst 1 by 1 by 2 cm. (Figs. 1 and 6). The cyst wall was firm, 3 mm. thick, and contained gray, inspissated mucoid material; microscopic examination of its wall (Fig. 9) revealed the structure of a large bronchus.

The lower lobe was atelectatic (Fig. 10), and cut section revealed an inordinate number of closely crowded bronchi. Detailed examination of the distribution of these bronchi confirmed the presence and arrangement of bronchi as represented on the composite bronchodiagram (Fig. 5).

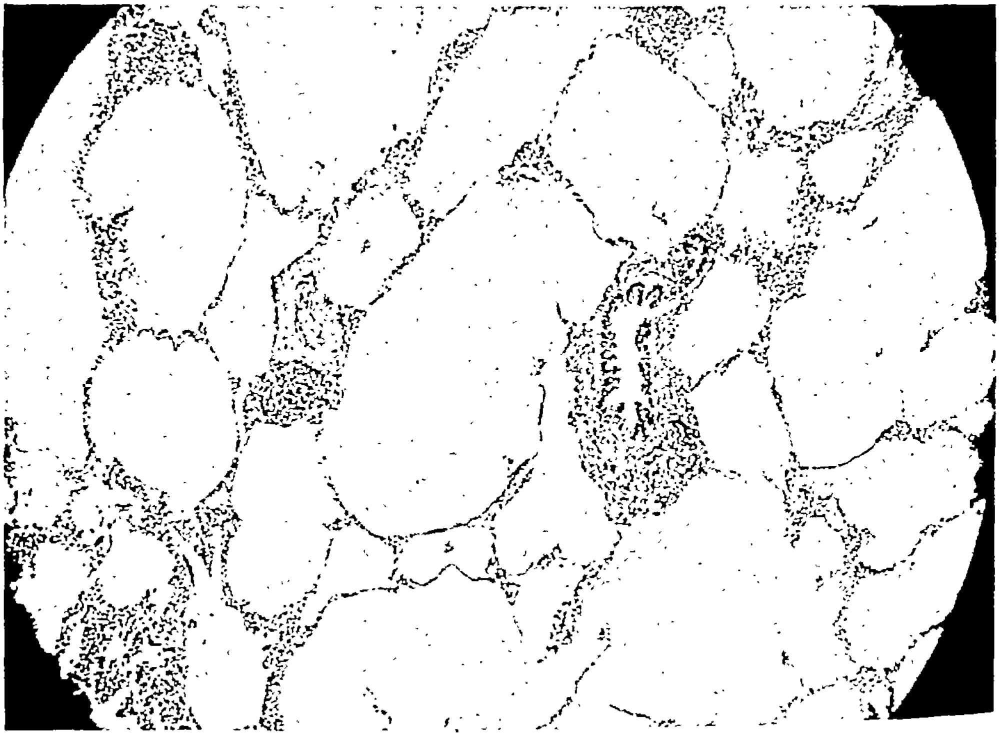
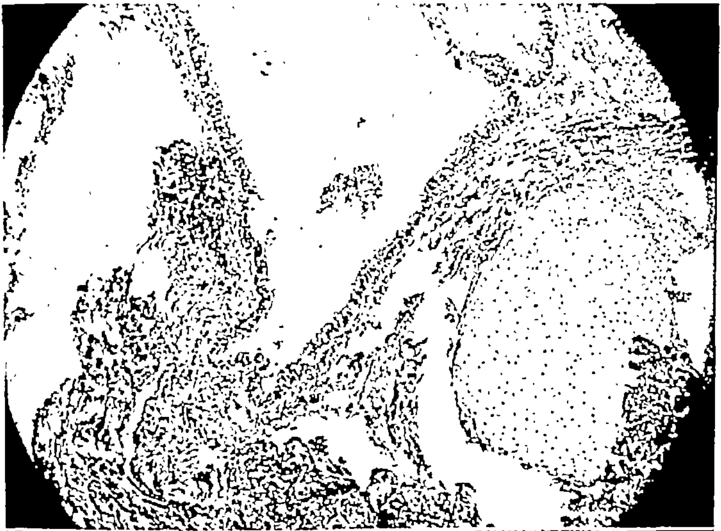


Fig. 8.—Illustrating bronchus and generalized emphysema of upper lobe (×79).

COMMENT

It has been assumed that the mesenchymatous anlage of a normal left lung gave rise to the two lobes of this specimen. The presence in the lower lobe of all the segmental bronchi normally found in an entire left lung has been interpreted as an ectopia bronchi of the left upper lobe. The posterosuperior segmental bronchi aerated but could not return air from the emphysematous, functionless upper lobe. Compression atelectasis of the lower lobe and mediastinal shift ensued. In the absence of a major bronchial communication from the upper lobe to the main bronchus it is impossible to explain the presence in that lobe of bronchi and of the bronchial cyst by the theory of lung formation propounded by Ekehorn[2] and Flint.[3] They described the development of branch bronchi as proceeding peripherally from the stem bronchus by a process of

Fig. 9.



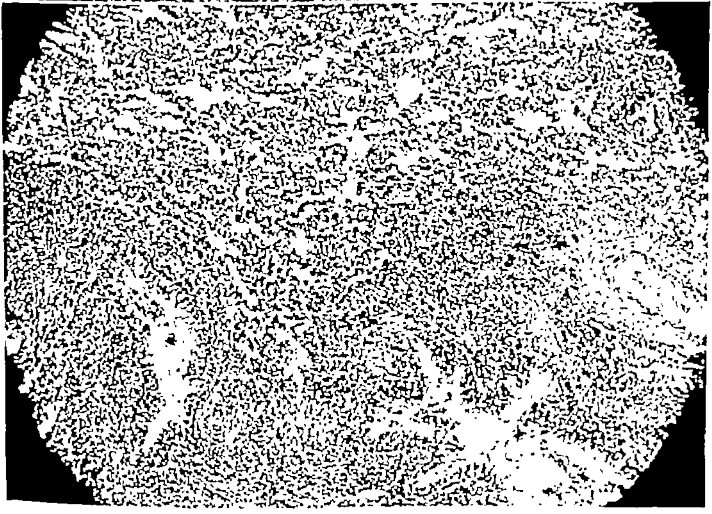


Fig. 10.

Fig. 9.—Illustrating bronchial epithelium and cartilaginous plate in wall of upper lobe cyst (×75).

Fig. 10.—Illustrating closely crowded bronchi and severe degree of lower lobe atelectasis (×75).

arborization. Heiss'[4] theory considers the stem bronchi as originating in the periphery of the lung and by a process of continuous infolding as giving rise to the connecting and terminal structures of the lung parenchyma. Such peripheral development has occurred in the case described; it but remained for the large bronchi arising centrally to join these smaller elements to complete a normal bronchial architecture of the upper lobe. Indeed, it would appear that here the mesenchymatous mass that Arey[1] denoted as contributing the nonepithelial elements to a lung had by a process of metaplasia given rise to bronchial epithelium. A more likely explanation is that the epithelium of the cyst and small bronchi arose from the bud of the left upper lobe bronchus, which bud later was incorporated into the lower lobe.

CONCLUSION

A case of ectopia bronchi of the left lung has been presented. Reference has been made to the prevailing theories of the development of the tracheobronchial tree and of the lungs, and the adequacy of these hypotheses has been questioned, particularly when reviewed in an effort to explain the anomaly described. If the knowledge of pulmonary embryology and the ability to diagnose lower respiratory tract anomalies is to keep abreast of recent advances in anatomy and surgery, detailed consideration must be given to a collection of many case reports such as that herein presented.

REFERENCES

1. Arey, L. B.: Developmental Anatomy, ed. 3, Philadelphia, 1937, W. B. Saunders Company, p. 210.
2. Ekehorn, G.: Ueber die Entwicklung der Lunge und insbesondere des Bronchialbaums beim Menschen, Ztschr. f. d. ges. Anat. 62: 271, 1921.
3. Flint, J. M.: The Development of the Lungs, Am. J. Anat. 6: 1, 1906.
4. Heiss, R.: Bau und Entwicklung der Wirbeltierlunge, Ztschr. f. d. ges. Anat. 24: 244, 1923.
5. Ferguson, Charles F., and Neuhauser, Edward B. D.: Congenital Absence of the Lung (Agenesis) and Other Anomalies of the Tracheobronchial Tree, Am. J. Roentgenol. 52: 459, 1944.
6. Gruenfeld, G. E., and Gray, S. H.: Malformations of the Lung, Arch. Path. 31: 392, 1941.
7. Schneider, P.: Die Missbildungen der Atmungsorgane; Jena, 1912; quoted by Elward, Joseph F.: Roentgen Aspects of Congenital Aplasia of Lung, Radiology 27: 667, 1936.
8. Jordan, Harvey: Anomalies of Human Respiratory System (A Proposed Classification), Am. Rev. Tuberc. 40: 517, 1939.
9. Caffey, John: Pediatric X-Ray Diagnosis, Chicago, 1945, The Year Book Publishers, Inc., p. 229.
10. Peeler, C. N., and Phillips, C. C.: Some Observations on Endoscopy, South. Med. & Surg. 84: 299, 1922.
11. Cassinelli, J. F.: Hipoplasia de un Bronquio Pedicular y Enfisema Lobar Agudo en un Lactante, Hoja tisiol. 4: 230, 1944.
12. Nelson, R. L.: Congenital Cystic Disease of the Lung, J. Pediat. 1: 233, 1932.
13. Morelli, J. B.: Disgenesias del Aparato Respiratorio: El Enfisema Gigante con Pulmonalitis Congenita, Prensa méd. argent. 23: 1411, 1936.
14. Harris, H. A., and Lewis, Ivor: Anomalies of the Lungs With Special Reference to the Danger of Abnormal Vessels in Lobectomy, J. Thoracic Surg. 9: 666, 1940.
15. Boyden, Edward A.: The Intrahilar and Related Segmental Anatomy of the Lung, Surgery 18: 706, 1945.
16. Jackson, Chevalier L., and Huber, John Franklin: Correlated Applied Anatomy of the Bronchial Tree and Lungs With a System of Nomenclature, Dis. of Chest. 9: 1, 1943.
17. Scannell, J. Gordon: A Study of Variations of the Bronchopulmonary Segments in the Left Upper Lobe, J. Thoracic Surg. 16: 530, 1947.

LUNG HERNIA

A Case Report and Review of Literature

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THE occurrence of a case of lung hernia on the surgical service of this hospital has stimulated me to review the available literature. Lung hernia is a relatively rare condition. Less than 200 cases of lung hernia have been reported in the literature. A number of the earlier cases cannot be considered as true hernias of the lung but were merely traumatic eviscerations or prolapse.

A true lung hernia is defined as a protrusion of the lung and its pleural membranes through an abnormal opening in the thoracic enclosure.

The first case of lung hernia was reported by Roland in 1499.[9] However, this probably was not a true hernia of the lung. Montgomery and Lutz[8] credited Plater with the first report of a case of true lung hernia in 1641. Since that time there have been scattered reports of individual cases in the literature. Up to 1800 only fifteen cases had been reported, nine of which were true lung hernias. Morel-Lavallée[8] in 1849 compiled a detailed study of the cases, described the symptoms, and classified pulmonary hernias.

In 1925, Montgomery and Lutz in an extensive review of the literature found 165 cases. Goodman[3] in 1933 compiled 171 cases from the literature. Maurer and Blades[5] made the most recent study of lung hernia and reported seven additional cases—the largest individual report in the recent literature.

CASE REPORT

Mr. L. C. B., aged 46 years, a steamfitter, entered this hospital on March 28, 1946, with a history of having been in an automobile accident at 6 A.M. March 27, 1946. On admission the patient was found to have multiple lacerations and abrasions about the face, head, and left side of the chest; marked subcutaneous emphysema of the chest wall and supraclavicular areas; and multiple fractures of the left sixth, seventh, eighth, and ninth ribs posteriorly. There was considerable displacement of the fractured segments of the sixth and seventh ribs. A left hemothorax and hemopericardium ensued but under conservative therapy spontaneous recovery occurred except for slight pain and tenderness in the region of the fractured ribs.

On Jan. 16, 1947, the patient was readmitted to this hospital complaining of pain in the left posterior portion of the chest. The patient stated that following previous hospitalization he was unable to work because of pain. The pains were described as beginning beneath the left scapula and radiating laterally to the left shoulder. The pains were burning in character, constant, and aggravated by coughing. The patient also complained of dyspnea and slight hemoptysis on several occasions.

Physical examination on admission revealed a well-developed and well-nourished white man, ambulatory and not acutely ill. Temperature was 98.6° F., pulse 100, and respiration 20. The right pupil was contracted and the left pupil dilated; pupillary reflexes were absent. There was marked dental caries. The chest was barrel-shaped; a depression was noted beneath the inferior angle of the left scapula over the sixth and seventh ribs posteriorly. The depression was partially covered by the scapula. There was a palpable defect in the chest

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arborization. Heiss'[4] theory considers the stem bronchi as originating in the periphery of the lung and by a process of continuous infolding as giving rise to the connecting and terminal structures of the lung parenchyma. Such peripheral development has occurred in the case described; it but remained for the large bronchi arising centrally to join these smaller elements to complete a normal bronchial architecture of the upper lobe. Indeed, it would appear that here the mesenchymatous mass that Arey[1] denoted as contributing the nonepithelial elements to a lung had by a process of metaplasia given rise to bronchial epithelium. A more likely explanation is that the epithelium of the cyst and small bronchi arose from the bud of the left upper lobe bronchus, which bud later was incorporated into the lower lobe.

CONCLUSION

A case of ectopia bronchi of the left lung has been presented. Reference has been made to the prevailing theories of the development of the tracheobronchial tree and of the lungs, and the adequacy of these hypotheses has been questioned, particularly when reviewed in an effort to explain the anomaly described. If the knowledge of pulmonary embryology and the ability to diagnose lower respiratory tract anomalies is to keep abreast of recent advances in anatomy and surgery, detailed consideration must be given to a collection of many case reports such as that herein presented.

REFERENCES

1. Arey, L. B.: Developmental Anatomy, ed. 3, Philadelphia, 1937, W. B. Saunders Company, p. 210.
2. Ekehorn, G.: Ueber die Entwicklung der Lunge und insbesondere des Bronchialbaums beim Menschen, Ztschr. f. d. ges. Anat. 62: 271, 1921.
3. Flint, J. M.: The Development of the Lungs, Am. J. Anat. 6: 1, 1906.
4. Heiss, R.: Bau und Entwicklung der Wirbeltierlunge, Ztschr. f. d. ges. Anat. 24: 244, 1923.
5. Ferguson, Charles F., and Neuhauser, Edward B. D.: Congenital Absence of the Lung (Agenesis) and Other Anomalies of the Tracheobronchial Tree, Am. J. Roentgenol. 52: 459, 1944.
6. Gruenfeld, G. E., and Gray, S. H.: Malformations of the Lung, Arch. Path. 31: 392, 1941.
7. Schneider, P.: Die Missbildungen der Atmungsorgane; Jena, 1912; quoted by Elward, Joseph F.: Roentgen Aspects of Congenital Aplasia of Lung, Radiology 27: 667, 1936.
8. Jordan, Harvey: Anomalies of Human Respiratory System (A Proposed Classification), Am. Rev. Tuberc. 40: 517, 1939.
9. Caffey, John: Pediatric X-Ray Diagnosis, Chicago, 1945, The Year Book Publishers, Inc., p. 229.
10. Peeler, C. N., and Phillips, C. C.: Some Observations on Endoscopy, South. Med. & Surg. 84: 299, 1922.
11. Cassinelli, J. F.: Hipoplasia de un Bronquio Pedicular y Enfisema Lobar Agudo en un Lactante, Hoja tisiol. 4: 230, 1944.
12. Nelson, R. L.: Congenital Cystic Disease of the Lung, J. Pediat. 1: 233, 1932.
13. Morelli, J. B.: Disgenesias del Aparato Respiratorio: El Enfisema Gigante con Pulmonalitis Congenita, Prensa méd. argent. 23: 1411, 1936.
14. Harris, H. A., and Lewis, Ivor: Anomalies of the Lungs With Special Reference to the Danger of Abnormal Vessels in Lobectomy, J. Thoracic Surg. 9: 666, 1940.
15. Boyden, Edward A.: The Intrahilar and Related Segmental Anatomy of the Lung, Surgery 18: 706, 1945.
16. Jackson, Chevalier L., and Huber, John Franklin: Correlated Applied Anatomy of the Bronchial Tree and Lungs With a System of Nomenclature, Dis. of Chest. 9: 1, 1943.
17. Scannell, J. Gordon: A Study of Variations of the Bronchopulmonary Segments in the Left Upper Lobe, J. Thoracic Surg. 16: 530, 1947.

intratracheal anesthesia an incision was made over the seventh rib extending from the transverse process posteriorly to the posterior axillary line. The incision was extended down through the muscle and fascia until the pleura was reached. In portions the pleura was found directly beneath the skin. The hernial sac consisted of diverticular outpouchings of the pleura extending out over the posterior surface of the ribs. The sac was dissected free. The sixth rib was found to be fractured in two places and the distal end of the middle fragment was embedded in the pulmonary tissue underlying the fifth rib. This was freed and brought up into the operative field. The seventh rib was similarly fractured with the fragment displaced down under the eighth rib. This was likewise freed and brought up into the operative field. The eighth rib had been fractured but had healed with only a moderate amount of deformity. Adhesions of the lung to the hernial sac were found and freed and the lung allowed to retract into the pleural cavity. The hernial sac was then removed and the edges of the pleura were approximated with No. 000 chromic catgut sutures. The ends of the seventh rib were freshened. Holes were bored into each end and a fine stainless steel wire was used to approximate them. The sixth rib was similarly treated. This brought the ribs fairly well into a normal alignment. The overlying muscles and fascia were then closed with interrupted chromic catgut sutures. The skin was closed with interrupted black silk sutures. The patient received 500 c.c. of citrated blood and 1000 c.c. of glucose in saline during the operative procedure.

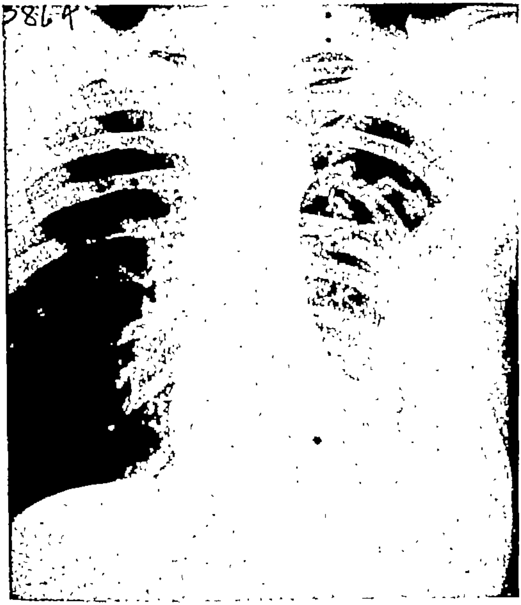

Fig. 2.—Postoperative chest x-ray view taken May 20, 1947. The defect in the thoracic cage has been corrected. Periosteal new bone formation is noted. There is mal-alignment of the fractures resulting from insufficient immobilization. Narrowing of the interspaces and thickening of the pleura in the left midportion and base are observed.

Postoperative course.—Shortly after the patient's return to his room respiratory embarrassment was noted, necessitating water-trap suction to reduce excessive pneumothorax;

suction was discontinued after two hours. General supportive therapy was instituted and penicillin was administered intramuscularly every three hours until Feb. 22, 1947. A moderately severe persistent cough associated with moderate mucopurulent sputum and left chest pains were noted postoperatively. X-ray examination of the chest on Feb. 4 showed some fluid in the left chest. This increased in amount, necessitating the aspiration of 870 c.c. of serosanguineous fluid on Feb. 10, 350 c.c. on Feb. 13, and 50 c.c. on Feb. 26; 100,000 units of penicillin were instilled into the pleural cavity after each thoracentesis. The sutures were removed on Feb. 10 at which time the wound edges appeared slightly reddened and indurated. The patient was allowed up in a wheel chair on the same date and soon thereafter was ambulatory. He developed a laryngitis on Feb. 20 which was treated with penicillin inhalations and responded slowly. The wound was well healed and when last seen in June, 1947, there was no evidence of recurrence of the lung hernia. The patient has vague chest and shoulder pains which seem to be greatly exaggerated. Re-check x-ray views on May 20, 1947, reveal some residual thickening of the pleura with narrowing of the interspaces on the left; at the site of the hernia repair there is some displacement of the rib fragments and evidence of periosteal new bone formation (Fig. 2).

DISCUSSION

The classification of lung hernias as devised by Morel-Lavalleé in 1849[9] and accepted by most authors is as follows:

- I. According to location:
    - A. Diaphragmatic
    - B. Thoracic
    - C. Cervical
- II. According to etiology:
    - A. Congenital
    - B. Acquired
        - 1. Traumatic
        - 2. Consecutive
        - 3. Spontaneous
        - 4. Pathologic

Korol,[6] Hartung,[5] and others question the occurrence of diaphragmatic lung hernia. There has been only one case reported in the literature. Beale[1] in 1882 reported the case of a 22-year-old white man who was pinned to the ground by a cart wheel striking him in the right abdomen. There was no external wound but autopsy revealed a defect in the right diaphragm through which the lung had apparently herniated with strangulation and abscess formation. Korol[6] considered this case as one of prolapse rather than herniation. Because of the pressure relationships, herniation of the lung through the diaphragm appears unlikely.

Korol[6] included mediastinal hernia in the category of lung hernia. A mediastinal lung hernia is a herniation of the lung through the mediastinal septum into the opposite hemithorax. Korol stated that it is the most frequent form of lung hernia, although few cases are noted in the literature to confirm this. It is said to occur frequently following modern collapse therapy (Korol, Hartung). The herniation occurs either anteriorly in the space between the sternum and the heart at the site of the atrophied thymus gland, or posteriorly between the esophagus and aorta below the level of the trachea and arch of the azygos vein. Mediastinal hernias are brought on by emphysema of one lung associated with contraction, atelectasis, or absence of the opposite lung. It may follow the abandonment of a long-continued pneumothorax. The pleural hernia of a tension pneumothorax is not to be confused with a mediastinal lung hernia.

Cervical lung hernias occur through the superior aperture of the thorax *between the sternocleidomastoid and scalenus anticus muscles and are due to a* tear or a deficiency of Sibson's fascia which normally limits the cervical excursion of the apex of the lung. Up to 1938 there had been only twenty cases reported in the literature.[6] They are usually said to be congenital.

The most common form of lung hernia is the thoracic or intercostal. Out of seventy-eight case reports reviewed by Montgomery and Lutz[9, 10] there were sixteen cervical hernias and sixty-two thoracic hernias. Thoracic hernias usually occur anteriorly near the sternum and posteriorly near the vertebrae. This is said to be due in each case to a locus minoris resistentiae in these areas, anatomically due to the fact that the external intercostal muscles extend forward only as far as the costochondral junctions and the internal intercostal muscles extend posteriorly only to the angle of the rib. Thoracic hernias are said to be more frequent anteriorly due to the fact that the pectoralis muscles cannot give as good support as the trapezius, latissmus dorsi, and rhomboideus muscles.

Montgomery and Lutz, in their review of 165 cases found in the literature, reported an incidence of 29 (18 per cent) congenital or early acquired hernias, 83 (50 per cent) traumatic, and 53 (32 per cent) spontaneous hernias. There has been some difficulty in determining whether a hernia is congenital or not. This is especially true when the hernia appears many months after birth. Hochsinger[11] stated that all hernias occurring in the first few weeks of life must be considered as congenital. Congenital lung hernias are due to several factors: (1) Weakness of the anatomic structures about the apex of the lung; (2) arrested growth of structures, that is, chest wall, sternal clefts; (3) intrauterine abnormalities such as pressure of an elbow against the fetal chest, amniotic bands, and pressure from tumors.

The great majority of acquired hernias are traumatic. A traumatic lung hernia may develop at any time after injury. Those first appearing late after injury have been classified by Morel-Lavallée as consecutive hernias. Most writers agree that this subdivision is superfluous and merely group all such cases as traumatic hernias. Traumatic hernias may develop following operative wound, penetrating or bullet wound, or crushing injuries. Lung hernias are only infrequently noted following chest surgery. Careful subperiosteal resection of the ribs in thoracoplasty and other chest surgery probably accounts for the rarity of this complication.

Spontaneous lung hernias are the result of two factors, namely, a locus minoris resistentiae (that is, an area of local decreased resistance in the boundaries of the chest cavity) and an abnormal increase in the air pressure in the alveoli of the lungs. The abnormal increase in the intrathoracic pressure may be due to various factors. Paroxysmal coughing, which may be due to a variety of conditions such as chronic bronchitis, bronchiectasis, whooping cough, pulmonary abscess, and foreign bodies of the lung, is an important etiologic factor.

Occupations, such as glass blowing and playing of wind instruments, have been found etiologically responsible for a number of cases. Violent muscular exertion, such as heavy weight lifting or childbirth, is a third factor in the occurrence of lung hernias.

Pathologic lung hernias result from a variety of diseases of the chest wall which produce a locus minoris resistentiae. Abscess of the chest wall and breast, perforating lung abscess or empyema necessitatis, and malignancies have all been responsible for the occurrence of pathologic lung hernias.

According to Montgomery and Lutz, lung hernias are three times more frequent in males. Other authors report an even greater incidence in males.

The symptoms of lung hernias are varied. Goodman[3] listed three cardinal symptoms as follows: bulge, cough, and pain at the site of the bulge. The onset is usually insidious accompanied by pain and cough. The cough is chronic, spasmodic, and may or may not be productive depending on the underlying pathology. Early, the traumatic hernias are usually obscured by the more severe signs and symptoms of injury. The hernia may rarely become incarcerated or strangulated producing inflammatory changes.

On physical examination there is noted a bulging mass which increases on forced inspiration. A defect in the chest wall is usually readily demonstrable. When the hernia is protuded, the soft spongy crepitant consistency of the lung may be noted. A scar may or may not be present depending on the etiology.

X-ray and fluoroscopy may be of assistance in demonstrating the defect of the chest wall and an area of increased translucency may be noted outside the normal pulmonary boundaries. In mediastinal hernias there may be an asymmetry of the chest and on x-ray examination a large hyper-aerated lung is seen to extend into the opposite side in one or two bulgings having definite convex outer borders. The upper bulge is anteriorly between the first and fourth ribs and the lower bulge is posteriorly between the fifth rib and diaphragm. The trachea and esophagus are displaced to the contracted side.

The diagnosis of lung hernia is not difficult if the condition is kept in mind. The physical findings are readily apparent. The differential diagnosis should be made from subcutaneous emphysema, perforating empyema, aneurysm of the intercostal vessels or aorta, fibroma, lipoma, and hemangioma. Mediastinal lung hernias must be differentiated from the pleural hernia of a tension pneumothorax in which there is no lung herniation present.

Complications are rare. Strangulation and gangrene of the lung may occur. Hemoptysis is not infrequent. The prognosis of lung hernia is good; it is rarely fatal, but rarely heals spontaneously.

The treatment of lung hernias is either medical or surgical. Medical treatment is in the main palliative consisting of rest, change of occupation, and local compression with pads and elastic devices. With palliative treatment the defect in the chest wall may become increasingly rigid, but the hernia, although smaller, will still persist; an increase in intrathoracic pressure will cause a return and increase in the size of the protusion. Surgery is contraindicated in a number of cases due to the underlying pulmonary pathology and general condition of the patient.

Surgery offers the only hope for a permanent cure. Various operative procedures have been devised. Vogler[5] in 1898 performed a plastic operation using *periosteum or bone flap from the sternum. Vulpius[8] in 1898 performed a plastic* operation in which he crossed strips of ribs which were sutured in place with silver wires; this hernia recurred in one year. Tuffler[4] in 1891 reported a cure by freeing and ligature of the hernial sac. Graham[4] in 1922 treated a spontaneous cervical hernia associated with an adenoma of the thyroid by excision of the adenomatous thyroid and packing of the wound with iodoform gauze. The packing was removed on the fifth postoperative day and the wound healed without recurrence of the hernia. Montgomery and Lutz[9] in 1925 reported a case of traumatic intercostal hernia cured by an osteoplastic procedure.

Goodman[3] in 1933 treated a traumatic consecutive intercostal hernia in a 42-year-old seaman by periosteal plastic closure. The redundant pleura was resected and closed with continuous catgut suture following which the periosteum of the rib above the defect was reflected downward, the periosteum of the rib below the defect was reflected upward, and both were sutured over the defect with chromic catgut.

Winkel[14] in 1935 reported a cure in a traumatic intercostal hernia by a repair consisting of weaving of fascia lata strips across the defect.

Repair of the defect with tantalum plate has been attempted by Paulson[8] but has been found unsatisfactory because of difficulty of immobilization of the chest wall.

These have in the main been individual case reports. Maurer and Blades[8] have undoubtedly had the largest individual experience with the surgical treatment of lung hernias in recent times. In 1946 they reported seven cases of traumatic intercostal lung hernias, four patients of whom submitted to surgery consisting of closure by periosteal flaps. In addition, they reported four cases of herniation of the liver and peritoneum through the lower thoracic cage which were repaired in a similar manner. Results have been excellent. Maurer and Blades believe that any defect of the chest wall regardless of size can usually be repaired by plastic procedures utilizing only structures which are a part of the chest wall, namely the rib, periosteum, and muscle. The most important feature is closure of the defect with sturdy bone or periosteum which will produce bone. The freeing of adhesions and of the lung about the margins of the defect with the creation of a local pneumothorax is important in the production of a cushion between the lung and the freshly repaired chest wall. This serves to reduce to a minimum the possibility of the lung being forced into the chest wall by coughing and straining during the immediate postoperative course.

SUMMARY

A review of the available literature concerning lung hernias has been presented.

A true lung hernia is a protusion of the lung and its pleural membranes through an abnormal opening in the thoracic enclosure. Its classification, etiology, symptoms, and treatment have been reviewed. The diagnosis is not difficult provided the condition is kept in mind.

The acute experiment was performed under sodium pentothal-sodium barbital anesthesia (sodium pentothal 20 mg. per kg., sodium barbital 150 mg. kg.). A rubber catheter was passed through the external jugular vein into the right ventricle under fluoroscopic guidance. At the time the dog was under the fluoroscope the state of the heart and lungs was noted. In no animal was there an accumulation of pleural fluid. Residual pneumothorax was minimal.

Right intraventricular pressure was measured through the intracardiac catheter by a water manometer; mean systemic blood pressure was measured from a cannula in a femoral artery. Cardiac output was estimated by the direct Fick principle, mixed venous blood being withdrawn from the catheter in the right ventricle and arterial blood being taken from the uncannulated femoral artery by needle puncture. Blood oxygen content was determined in duplicate by the method of Van Slyke and Neill. Oxygen consumption was measured continuously with a modified Roth-Benedict spirometer. An endotracheal catheter attached directly to the spirometer eliminated the necessity for tracheotomy. Leakage of air around the catheter was prevented by inflating a thin rubber cuff fitted to the outside of the catheter. This method made it possible to record any changes in tidal air and rate of respiration as well as oxygen consumption.

Records were made until the dog was in a steady state, usually one to two hours after the anesthesia had been given. Simultaneous arterial and right ventricular blood samples were then collected for estimation of the cardiac output. The ligature about the lung root was tightened by pulling on the end protruding through the chest wall. Occlusion was complete in 4 to 8 seconds. During this period continuous recordings were made of oxygen consumption, tidal volume, right intraventricular pressure, systemic blood pressure, and Lead II of the electrocardiogram. Within 5 minutes of ligation samples of blood were again drawn for the second cardiac output determination. The recordings were continued one to two hours or until the animal died.

A total of twenty dogs were studied. Autopsies were done in all cases. The condition of the lungs, the effectiveness of the ligature about the lung root, and the state of the heart were observed. In all instances the ligature effectively occluded the bronchus and accompanying blood vessels.

RESULTS

The sudden ligation of one lung root caused an immediate rise in right intraventricular pressure of from 20 to 129 mm. of water (average 57 mm.) lasting 3 to 60 minutes (average 25 minutes). There was a transient slowing of the heart for 4 to 5 beats but no other change in the electrocardiogram. Systemic blood pressure showed a transient fall of 10 to 15 mm. Hg during the time the ligature around the lung root was being tightened but rose again to the preligation level and remained steady (Fig. 1).

In eight dogs the changes in cardiac output after ligation of the lung root were no more than ± 200 c.c. per minute (from ± 5 to 17 per cent of the control value), and these were considered insignificant variations. (Significance was based upon both the limits of accuracy of the method for determination of oxygen content of the blood samples and changes in output which might reasonably be expected to occur over a ten-minute period under barbiturate anesthesia.[9, 10]) In three dogs there were increases in cardiac output of 400 c.c., 800 c.c., and 1,900 c.c. per minute (+ 25 per cent, 32 per cent, and 63 per cent). In six instances the output decreased 300 c.c. to 700 c.c. per minute (18 to 45 per cent), and in two the outputs fell 1,600 c.c. and 1,900 c.c. per minute, decreases of 53 per cent and 68 per cent.

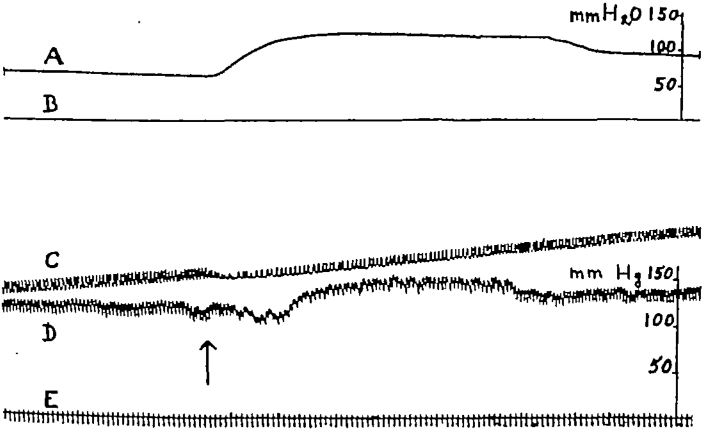

Fig. 1.—Effects of ligation of right lung root (Dog 16) at arrow. *A*, Right intraventricular pressure; *B*, base line at level of right atrium; *C*, respiration and oxygen use; *D*, mean arterial blood pressure (femoral artery); *E*, base line for blood pressure, 4 second intervals.

The oxygen consumption before and after ligation remained essentially the same. In twelve dogs the minute volume of respiration did not change significantly; in four of these neither the tidal air nor the rate of respiration changed, and in eight an increase in rate of respiration was proportional to a decrease in tidal air. (Significance was based on the fact that, with the spirometer used, tidal air could be estimated within 10 c.c. A change in minute volume of less than ten times the rate of respiration was considered insignificant.) The minute volume decreased 300 to 800 c.c. (19 to 25 per cent) in four dogs; in three of these this was due to a decrease in tidal air without a completely compensatory increase in rate, and in one exceptional case in which respiration became suddenly slower and deeper the decrease in rate (41 per cent) was greater than the increase in tidal air (37 per cent). The minute volume increased 1,000 to 1,100 c.c. (30 to 44 per cent) after ligation in four instances due to a very large increase in rate of respiration (25 to 59 per cent) out of proportion to any change in tidal air.

In the twelve dogs with no significant change in over-all minute volume there was no significant change in the efficiency of respiration as measured by the ventilation equivalent. (Ventilation equivalent = liters of air necessary to be ventilated for the absorption of 100 c.c. of oxygen.[8]) With an increase in minute volume, the efficiency decreased (ventilation equivalent increased); with a decrease in minute volume efficiency of oxygen absorption increased (ventilation equivalent decreased).

TABLE I. CARDIOVASCULAR FUNCTION BEFORE (A) AND AFTER (B) PNEUMONECTOMY

		CARDIAC OUTPUT (LITERS PER MIN.)			STROKE VOL. (C.C.)		PULSE		RT. VENT. PRESS. MM. OF H_2O			
NO.	LUNG	A	B	PER CENT CHANGE	A	B	A	B	RISE	TIME TO RETURN (MIN.)	ART. B.P. CHANGE	AUTOPSY ABNORMAL FINDINGS
1	RPA	1.9	2.0	+ 5								
2	LL	1.2	1.0	–17								
3	RL	1.9	1.8	– 5								RLL abscess
4		2.5	3.3	+32								
5	RL	0.7	0.4	–42	5.4	2.7	140	148				
6	RL	1.1	0.6	–45	6.5	3.2	168	190				
7	RL								28	8		
8	RL	2.1	1.9	– 9	17.5	16.5	120	114	81	60		LUL, LML atelectatic
9	LL	3.0	4.9	+63	18.7	36.2	160	135	36	15		LLL atelectatic
10	LL	2.2	2.1	– 5	14.5	14.0	160	150	None			
11	RL	0.5	0.3	–40	3.8	2.1	130	140	70	30	No change	RLL, atelectatic
12	RL	1.2	1.2	0	6.3	7.6	190	170	80	30		
13	RL	2.8	0.9	–68	16.5	5.3	170	170	105	30	Fell, Died	Infarct RLL, RML, worms right heart
[illegible]	RL	1.8	1.3	–27	9.5	8.1	190	160	20	15		Infarct RLL
15	RL	2.1	1.9	– 9	10.0	7.6	210	250	55	30	Sl. fall	
16	RL	3.8	3.1	–18	23.4	17.2	162	180	117	25	No change	Infarct RLL
17	RL	3.0	1.4	–53	20.0	10.0	150	140	59	60	Fell	
18	RL	1.5	1.9	+26	10.0	12.6	150	150	40	17	No change	
19	RL	2.2	1.7	–23	15.7	14.2	140	120	40	7	Sl. rise	Catheter Rt. atrium
20	RL	1.2	1.3	+ 8	7.6	8.7	170	150	20	3	No change	

At the end of the acute experiment eighteen of the twenty dogs had apparently compensated for the functional removal of one lung. The blood pressure had been maintained and there was no respiratory difficulty. Two failed to compensate. One of these showed a decrease in cardiac output from 2.8 to 0.9 liters per minute, the stroke volume falling from 16.5 to 5.3 c.c. Systemic blood pressure fell immediately from 72 mm. Hg to 54 mm. Hg, rose to 86 mm. and then fell gradually until death occurred at the end of one hour. At autopsy the heart was found to be dilated and the right heart and pulmonary artery filled with the round worms *Dirofilaria immitis*. On section the blood vessels in the lung were also found to be full of microfilariae of *D. immitis*. The cardiac output of the second dog fell from 3.0 to 1.4 liters per minute, the systemic blood pressure decreased gradually from 130 to 64 mm. Hg, and Traube-Hering waves appeared. After two hours the animal appeared unlikely to recover and was sacrificed. At autopsy the heart and lungs were grossly normal.

DISCUSSION

The conditions under which the experiment was carried out were admittedly not entirely normal. Barbiturate anesthesia is known to decrease the cardiac

Table II. Pulmonary Function Before and After Pneumonectomy

NO.	LUNG	O_2 USE C.C. PER MIN.		MIN. VOL. LITERS PER MIN.		TIDAL AIR (C.C.)		RESP. RATE PER MIN.		VENT. EQUIV. L. PER 100 C.C.		AUTOPSY, ABNORMAL FINDINGS
		BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	BEFORE	AFTER	
1	RPA	62	62	4.5	4.5	42	42	108	108	7.3	7.3	
2	LL	35	35	3.7	4.7	83	52	45	88	1.1	1.3	
3	RL	42	44	2.7	2.7	71	71	38	38	6.4	6.1	RLL Abscess
4		56	62	2.5	3.6	67	73	38	49	4.5	5.8	
5	RL	52	53	3.6	3.2	83	54	43	50	6.9	6.0	
6	RL	30	30	1.6	1.3	72	52	22	25	5.3	4.3	
7	RL	46	43	2.0	2.2	100	100	20	22	4.4	5.1	
8	RL	60	67	3.4	3.0	62	52	55	57	5.7	4.4	LUL, LML atelectatic
9	LL	74	74	3.7	3.0	83	114	44	26	4.9	4.0	LLL atelectatic
10	LL	53	53	2.8	3.8	104	98	27	30	5.3	7.2	
11	RL	25	25	3.6	4.7	108	93	33	50	1.4	1.9	RLL atelectatic
12	RL	52	59	2.7	3.8	93	83	20	46	5.2	6.5	
13	RL	64	57	3.4	3.0	89	72	38	42	5.3	5.3	Infarct RLL, RML, worms right heart
14	RL	49	46	1.9	1.3	62	39	30	32	3.8	2.7	Infarct RLL
15	RL	242	242	3.7	4.3	62	55	60	78	1.5	1.8	
16	RL	83	85	3.0	3.2	166	145	18	22	3.6	3.8	Infarct ½ RLL
17	RL	62	55	1.3	0.7	35	13	36	51	2.0	1.2	
18	RL	83	83	3.2	2.4	83	52	39	46	3.9	2.9	
19	RL	83	71	2.2	2.0	42	42	53	48	2.7	2.8	
20	RL	73	80	3.6	3.7	125	93	29	40	5.0	4.7	

output of an animal.[8, 10] According to Shore and associates[9] the decrease in cardiac output with anesthesia is neither constant nor predictable. Over 20 to 30 minute periods they cite decreases of from 10 to 30 per cent, and, on the other hand, over some 90 minute periods they have found decreases of only 6 to 7 per cent. In our studies the two estimations of cardiac output were made not more than 10 minutes apart, and at least 60 minutes after induction, hence, since the animal was in a steady state with regard to blood pressure and oxygen consumption when the ligature was tightened, it may be assumed that any change in cardiac output more than 10 per cent in the period immediately following could be attributed to the manipulation.

The experiments were done with the chest closed to enable a continuous recording of both oxygen consumption and the details of pulmonary ventilation. The dog was breathing against a definite resistance at all times, but this resistance was constant, and relative changes in the character of respiration were readily seen.

Since we found the right pulmonary artery to be slightly larger in diameter than the left, the right side was used after the first few experiments as the side which might be expected to give the greater changes.

Compensatory circulatory and respiratory mechanisms were sufficient in all but two dogs to maintain the systemic blood pressure and the oxygen consumption virtually unchanged. This speaks for the large reserves of the vascular bed and airways of one lung which can immediately take over the functions of two.

The outstanding change in the cardiovascular system, which occurred in all but one instance, was an increase in right intraventricular pressure. This rise was relatively slow in development, taking from 2 to 10 minutes to reach its peak, remaining on a plateau for 10 to 15 minutes, and gradually falling to the preligation level in 25 to 30 minutes. It was not correlated with changes in cardiac output, stroke volume, or systemic blood pressure. One might expect that the sudden removal of a large part of the pulmonary capillary bed would result in greatly increased resistance in the pulmonary circuit. The return of the ventricular pressure to its former level suggests that additional vascular channels were opened, or that existing vessels increased in size under the increased pressure. This opening of a reserve vascular bed has been postulated previously by Tigerstedt[11] and by Wiggers.[12]

The cardiac output following compression of the pulmonary artery has been of interest to many observers. In 1907 Tigerstedt,[11] measuring the minute output of the left heart with a stromuhr, found that it was only slightly decreased by ligation of the left pulmonary artery. Haggart and Walker,[13] in nine experiments on cats, also found only a slight decrease in cardiac output with compression of the left pulmonary artery. Fineberg and Wiggers[6] found decreases in left ventricular output with compressions of the pulmonary artery exceeding 41 to 72 per cent (average 58 per cent).

In the present studies there was no change in cardiac output in eight experiments. In three the output increased. In eight there was a significant decrease in cardiac output following ligation of a lung root. With a decrease in cardiac output up to 45 per cent, compensatory mechanisms were adequate to prevent a change in systemic blood pressure. In the two cases in which the cardiac output fell 53 and 68 per cent the arterial blood pressure fell steadily over the remainder of the experimental period.

The changes in cardiac output, when they occurred, appeared to depend largely on changes in stroke volume. Although the heart rate was usually somewhat altered by ligation of the lung root (average change plus or minus 19 beats per minute), the direction of change was unpredictable and the magnitude not sufficient in itself to effect a significant increase or decrease in cardiac output if not associated with a similar change in stroke volume. Out of a total of fifteen dogs, eight showed changes in stroke and pulse opposite in direction; five resulted in significant changes in output in the direction of the change in stroke volume. Two dogs maintained a constant heart rate but variations in stroke volume were sufficient to bring about significant alterations in cardiac output. In three instances in which there was a significant decrease in cardiac output, changes in stroke volume and heart rate were parallel.

With ligation of one lung root a certain volume of blood is trapped in the lung. What part this plays in the reductions of cardiac output in these experiments is not known.

There was a transient drop in systemic blood pressure which occurred as the ligature was being pulled tight. Parin[14] has described a fall in systemic blood pressure which he believes due to a reflex mediated through the vagus nerve from pressoreceptors in the pulmonary artery. The pressures used by Parin experimentally were 40 mm. of Hg or above. In the present studies the pressures in the right ventricle, and therefore in the pulmonary artery, did not approach 40 mm. of Hg. Furthermore, the transient fall in blood pressure did not coincide with the rise in right intraventricular pressure but preceded it. The transient blood pressure drop did coincide with a brief slowing of the heart, and was probably caused by vagal stimulation set up by tugging on the lung root. Vagal arrest never occurred.

The adjustment of the respiratory system to the sudden removal of one functioning lung was complete in that oxygen continued to be absorbed at a constant rate. It is obvious, then, that the remaining lung began immediately to absorb as much as double the oxygen it had absorbed prior to ligation.

The changes in ventilation of the remaining lung were unpredictable. Theoretically, oxygen consumption could be increased by either increasing the minute volume of respiration or the efficiency of oxygen absorption or both.

In over one-half the dogs the recorded minute volume did not change, which means, in actual fact, that in these cases the minute volume of the one remaining lung approximately doubled. Two factors determine minute volume: rate of respiration and tidal air. Over-all minute volume was maintained unchanged either by a large increase in tidal air of the remaining lung or by a smaller increase in tidal air together with an increase in respiratory rate.

In other dogs there was altered efficiency of oxygen absorption, as m by the ventilation equivalent, due to changes in the minute volume af tion and no real change in oxygen use. Since the ventilation equivalent is a ratio between the minute volume and the oxygen uptake, it varies as these two factors vary. The rate and depth of respiration are controlled by complex nervous and chemical mechanisms. Oxygen absorption in the lungs, on the other hand, is a physical process depending upon such conditions as the permeability of the alveolar and capillary membranes, the area of the absorbing surfaces, the time of exposure of the blood to the alveolar air, the total volume of blood exposed to the alveolar air in any period of time, and the difference in partial pressure of the oxygen of the alveolar air and the blood of the pulmonary artery. Minute volume and oxygen consumption may vary independently, and the ventilation equivalent may be affected by alterations in either. For example, in Dog 18 the ventilation equivalent before ligation was 3.9, for 30 seconds after ligation the tidal air was very small and the rate of respiration slow, but oxygen use was not reduced proportionally to minute volume. The ventilation equivalent at this time was 1.8. Respiration gradually became deeper and faster; oxygen consumption returned to the preligation level and the ventilation equivalent became 2.9. These changes in ventilation equivalent denoting altered efficiency of oxygen absorption per liter of ventilated air depend upon reduction of minute volume of respiration rather than changes in oxygen uptake following ligation. Oxygen absorption was but little affected by the operative manipulation, whereas respiratory movements were momentarily inhibited, presumably through nervous reflex mechanisms.

Since the ventilation equivalent which relates the two factors of minute volume and oxygen uptake is not a constant, it does not appear to be a necessarily reliable index of respiratory function, at least when conditions are basal. There is, of course, a limit to the capacity of a lung to absorb oxygen. This limit may be reached more quickly in lungs with diseased alveolar membranes or greatly decreased alveolar surfaces. To approach such a limit would mean increasing the oxygen demand until the lowest possible ventilation equivalent had been attained. Under such conditions of stress the ventilation equivalent might prove to be a better criterion of cardiorespiratory function.

These studies do not indicate to how much additional stress, such as exercise or an increased blood volume, an animal could adjust after pneumonectomy. Longacre and associates[15, 16] found some indication of the loss of cardiorespiratory reserve after pneumonectomy in chronic experiments measuring responses of dogs to exercise, using pulse, respiratory rate, body temperature rise, and arterial oxygen saturation as criteria of function.

Ligation of one lung root does put increased stress on the right ventricle. Right intraventricular pressure increased in all but one of the cases measured. Fineberg and Wiggers[6] have found that the right ventricle, like the left, is able to meet increased peripheral resistance by an increased force of contraction, but that the range of compensation is extremely narrow. Almost all of our dogs were able to adjust to the added stress put on the right ventricle. Although 40 per cent showed an immediate reduction in cardiac output, systemic blood pressure was maintained. What happened to the cardiac output in the succeeding hours was not determined. Tying off the right branch of the pulmonary artery is equivalent to occlusion of at least 50 per cent of the pulmonary artery. Fineberg and Wiggers found one dog in their series which was unable to maintain right ventricular output unchanged when 41 per cent of the pulmonary artery was occluded. One dog in our series with apparently normal heart and lungs was unable to maintain the systemic blood pressure after sudden pneumonectomy.

With the pulmonary vascular bed cut in half, it might be expected that the pressure in the pulmonary circuit would be increased more readily. Gibbon, Gibbon and Kraul[17] showed that in cats when the right middle and lower lobes and all of the left lower lobes were removed a blood transfusion of 15 c.c. per kg. caused death due to pulmonary edema in four out of nine animals. A similar type of study before and after pneumonectomy might prove enlightening.

In conclusion, the majority of dogs in this series were able to make physiologic adjustments to the functional loss of one lung; two dogs, one with heart disease and one with apparently normal heart and lungs, were not. No attempts were made to measure the cardiorespiratory reserves after such a procedure.

SUMMARY

1. The details of cardiovascular and respiratory adjustment to functional pneumonectomy were studied in twenty dogs with closed chests. Pneumonectory was accomplished under barbiturate anesthesia by the sudden ligation of one entire lung root.

2. The immediate response of the cardiovascular system was a rise in right intraventricular pressure, and, in 40 per cent of the dogs, a decrease in cardiac output. Systemic blood pressure was usually maintained.

3. Oxygen consumption before and after ligation was essentially unchanged.

4. The changes in pulmonary ventilation were unpredictable and consisted of increases in tidal air of the remaining lung, increases in rate of respiration, and altered efficiency of oxygen absorption.

5. Two dogs were unable to compensate for this functional pneumonectomy. One showed cardiac disease, and one had apparently normal heart and lungs.

REFERENCES

1. Lichtheim: Die Storungen des Lungenkreislaufs und ihr Einfluss auf den Blutdruck, Inaug. Dissert. Berlin, 1876; Quoted by Plumier.[3]
2. Gerhardt, D.: Experimentelle Beitrage zur Lehre vom Lungenkreislauf und von der mechanischen Wirkung Pleuritischen Ergusse. Ztschr. f. klin. Med. 55: 105, 1904.
3. Plumier, L.: La Circulation Pulmonaire chez le Chien, Arch. internat. de physiol. 1: 170, 1904.
4. Welch, W. H.: Zur Pathologie des Lungenodems, Virchows Arch. f. path. Anat. 72: 375, 1878.
5. Gibbon, J. H., Hopkinson, M., and Churchill, E. D.: Changes in the Circulation Produced by Gradual Occlusion of the Pulmonary Artery, J. Clin. Investigation 11: 543, 1932.
6. Fineberg, M. H., and Wiggers, C. J.: Compensation and Failure of the Right Ventricle, Am. Heart J. 11: 255, 1936.
7. Andrus, W. D. W.: Observations on the Total Lung Volume and Blood Flow Following Pneumonectomy, Bull. Johns Hopkins Hosp. 34: 119, 1923.
8. Pinner, M.: Pulmonary Tuberculosis in the Adult, Springfield, Ill., 1945, Charles C Thomas, Publisher.

9. Shore, R., Holt, J. P., and Knoefel, P. K.: Determination of Cardiac Output in the Dog by the Fick Procedure, Am. J. Physiol. 143: 709, 1945.
10. Price, P. M., Hanlon, C. R., Longmire, W. P., and Metcalf, W.: Experimental Shock; I. Effects of Acute Hemorrhage in Healthy Dogs, Bull. Johns Hopkins Hosp. 69: 327, 1941.
11. Tigerstedt, R.: Neue Untersuchungen über die von dem linken Herzen Herausgetriebene Blutmenge, Skandinav. Arch. f. Physiol. 19: 1, 1907.
12. Wiggers, C. J.: The Regulation of the Pulmonary Circulation, Physiol. Rev. 1: 239, 1921.
13. Haggart, G. E., and Walker, A. M.: The Physiology of Pulmonary Embolism as Disclosed by Quantitative Occlusion of the Pulmonary Artery, Arch. Surg. 6: 764, 1923.
14. Parin, V. V.: The Role of Pulmonary Vessels in the Reflex Control of the Blood Circulation, Am. J. M. Sc. 214: 167, 1947.
15. Longacre, J. J., Carter, B. N., and Quill, L. McG.: An Experimental Study of Some of the Physiologic Changes Following Total Pneumonectomy, J. Thoracic Surg. 6: 237, 1937.
16. Carter, B. N., Longacre, J. J., and Quill, L. McG.: An Experimental Study of the Changes in Cardiorespiratory Physiology Following Total Pneumonectomy in Young Developing Animals, J. Thoracic Surg. 7: 326, 1937.
17. Gibbon, J. H., Gibbon, M. H., and Kraul, C. W.: Experimental Pulmonary Edema Following Lobectomy and Blood Transfusion, J. Thoracic Surg. 12: 60, 1942.

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Original Communications

THE SEGMENTAL AND LOBULAR PHYSIOLOGY AND PATHOLOGY OF THE LUNG

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THE introduction of the concept of segmental resection of the lung opened what was referred to at that time as an unwritten chapter in surgical anatomy. This chapter is now quite complete, and gratitude is expressed to Brock, Blades, Huber, Boyden, Scannell, and others for their painstaking contributions to descriptive anatomy. Mastery of the three dimensional intricacies of the interlacing bronchi and blood vessels is now an essential step toward the attainment of the precision required in present-day pulmonary surgery Attention is now directed to another chapter that awaits development—the segmental and lobular physiology and pathology of the lung. Some of the material is available and a firm structural basis has been provided by William Snow Miller, but the parts remain insufficiently related and incomplete. While the concepts that are certain to emerge may not guide our dissections, they will provide us with methods that are based on a more complete understanding of the organ with which we work.

Tribute is paid immediately to the brilliant contribution of Van Allen and Lindskog on collateral ventilation and the aerodynamics of bronchial obstruction presented to this Association many years ago. I shall return to this later on, but wish to comment now on the fact that this discovery was made by surgeons. Physiologists have been slow to accept the results of the easily repeated experiments and the significance of the mechanism has never received the attention it deserves. Possibly one reason is that physiologists are in the habit of dealing with the two lungs as a single organ. It has been their custom to select the trachea as the site to introduce resistance to the entrance and exit of air when experiments are designed to study the aerodynamics of respiration. Similarly the analysis of pulmonary edema has been approached through the mimicry of cardiac failure with abnormal conditions imposed upon the pulmonary circulation

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as a whole, or through the inhalation of irritant gases that are dispersed throughout the entire respiratory tract.

The bronchopulmonary segment with its component lobules is a physiologic unit of the lung just as the segment is a surgical unit of the lung and has become a unit of roentgenologic diagnosis. At the level of the segment or the lobule, obstruction to the outflow of air produced by disease or by neuromuscular action can produce volume and tension changes within a limited lung area at the expense of volume alterations in adjacent areas. The potentialities of this mechanism are lost sight of when all lobules and segments are subjected to identical conditions, which is the case when obstruction or resistance is imposed at the level of the trachea. The discovery of collateral air drift by Van Allen and Lindskog brought emphasis to this important difference.

The increased tension of the air within alveoli that is produced by partial occlusion of the bronchus to an entire lobe is referred to clinically as obstructive emphysema. The mechanism of its production by partial occlusion of the lumen and a widening of the air passages on inspiration and a narrowing on expiration is understood. The basic condition is obstruction to the outflow of air. Similarly, the acute lobar collapse caused by complete bronchial obstruction and absorption of the alveolar air is recognized experimentally and clinically. Both the collapse and the obstructive emphysema that might be expected to occur by the same mechanisms acting within the bronchopulmonary segment are subject to the special conditions imposed by collateral air drift and also by the secretory activity of the bronchial mucous membrane. These will be discussed. I shall, however, begin with the single lobule or a cluster of adjacent lobules and consider the significance of increased tension of the air within the alveoli and a possible relationship to the onset of pulmonary edema.

The several factors that control the passage of exudates and transudates across the wall of the capillary need not be enumerated. They are itemized in a diagram by Drinker (Fig. 1). Attention will be confined to the physical force studied by Landis and Gibbon[1] that assists in the control of filtration edema in the extremities, increasing tissue pressure. These authors measured the effects of the pressure that is built up by an increasing volume of fluid in the tissue spaces as the elasticity of separated tissue elements is encountered. This pressure opposes the filtration pressure within the capillary and slowly brings the leakage from capillaries to a halt. When one attempts to visualize the possibility of such a force acting in pulmonary tissue it is apparent that the unique structure of the lung creates a set of conditions different from those that exist in the tissues of the extremities. The lung tissue may undergo alterations in volume without creating pressure changes of any considerable magnitude. Tissue pressure built up by fluid escaping from the capillaries is a control measure that could be effective in the lung only when carried to the extreme of lobar consolidation, at which point the effect of the limiting membrane of the visceral pleura might be felt. In any event, the control force studied by Landis and Gibbon would be intolerable in the respiratory organs, for leakage from pulmonary capillaries into alveolar spaces is immediately destructive to the primary function of the lung.

In the lung the equivalent of mounting tissue pressure from fluid may be found in increased tension of the alveolar air. As long as the increased tension is confined to a lobule or segment, this portion of lung can distend through encroachment on adjacent lung without appreciable respiratory embarrassment. Were the mechanism activated in all portions of the lung simultaneously, a crisis of labored breathing, anoxia, and, at times, death would be expected, as is the actual fact in bronchial asthma.

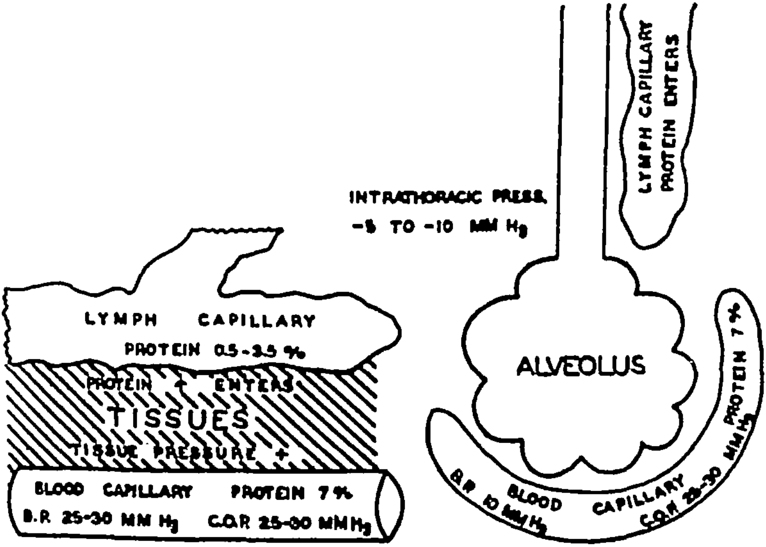


Fig. 1.—Diagrams of contrasting fundamental physiologic relations between blood capillaries and tissues. On the left, a representation of typical relations in the skin; on the right, relations in the lungs. (From Drinker: Pulmonary Edema and Inflammation, Harvard University Press.)

To postulate this happening in a portion of lung threatened by edema requires an explanation for the occurrence of obstruction to the outflow of air from a single area. This is known to occur locally in tension cysts and cavities, but in such instances is usually traced to a valve-like fold of mucous membrane or other "ball-valve" mechanism inherent in the pathologic lesion. In normal lung this action could arise from local reflex activation of the neuromuscular apparatus of the bronchi, for the vegetative neuromuscular apparatus of the human lung appears concentrated in the bronchial tree. It is true that the pulmonary arteries are possessed of smooth muscle but the weight of present evidence indicates that the lesser circulation is regulated in a passive manner except perhaps under certain emergency situations. The elaborate neuromuscular structure that surrounds the air passages has been described in detail (Fig. 2). The constant and vigorous activity of this apparatus has been expressed by Macklin[2] in the concept of the dynamic bronchus. Far from being rigid tubes, the bronchi undergo inspiratory dilatation with lengthening and expiratory construction with shortening. The walls of the alveoli do little or no stretching and the factor of safety of their elastic tissue is said to be slight.

The bronchial musculature is projected along the bronchiole and respiratory bronchiole to form sphincters about the openings into the atria. Sphincters are also formed about the openings into the alveoli that arise directly from the respiratory bronchiole. Trapping of air in the alveoli by obstruction to its outflow may well result from the sphincteric action of the bronchiolar musculature. The increased tension of the trapped air is dependent upon cough or expiratory grunting. Cough is known to have a twofold effect: The forcing of air into alveoli by the increased pressure built up within the air passages, as well as the expulsion of mucus from the upper portions of the tracheobronchial passages that comes on release of the laryngeal sphincter. Fluoroscopists are completely familiar with the increased radiance of the apical segments when they "light up" with cough; also with the dispersion of lipiodol from bronchi into alveoli

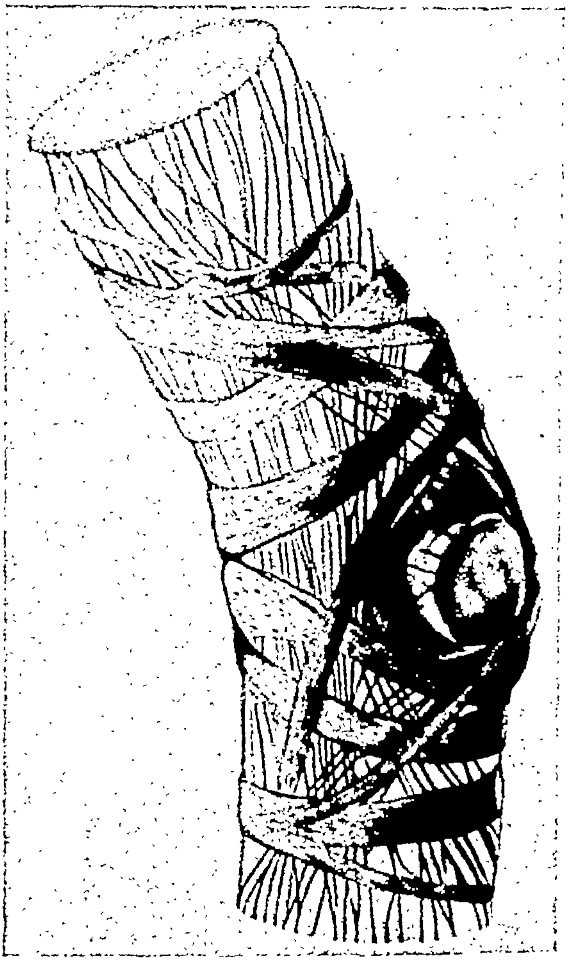


Fig. 2.—Arrangement of smooth muscle bands and elastic fibers. (From Miller: The Lung. Charles C Thomas, Publisher.)

with cough. The irritative nonproductive cough that attends the onset of pneumonia or ushers in a paroxysm of asthma thus provides a protective measure that builds up air tension in alveoli to support the capillary walls by external pressure.

The sequence of events may be pictured somewhat as follows (Fig. 3): (1) inspiratory widening of the terminal bronchioles; (2) early in expiration the quick closure of the laryngeal sphincter with elevation of endobronchial air tension by the muscular effort of a cough or grunt; (3) trapping of air in lobules under increased tension; (4) slow reduction in the tension by collateral air drift through the pores so that on the next cough the lobule receives a blast of fresh air with renewed oxygen supply.

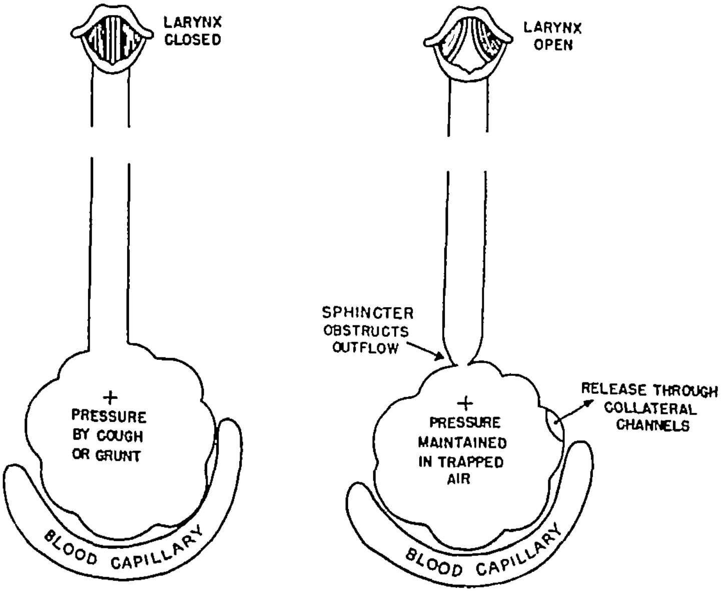

LARYNX CLOSED
+
PRESSURE BY COUGH OR GRUNT
BLOOD CAPILLARY
LARYNX OPEN
SPHINCTER OBSTRUCTS OUTFLOW
+
PRESSURE MAINTAINED IN TRAPPED AIR
RELEASE THROUGH COLLATERAL CHANNELS
BLOOD CAPILLARY

Fig. 3.—Diagram representing mechanism to establish and maintain intra-alveolar air pressure supporting capillary wall in a segment or subsegment of lung.

Surgeons of World War II, faced by localized pulmonary edema resulting from the direct trauma of a chest wound, found that the effective course of management lay in clearing the upper respiratory passages, controlling pain by intercostal nerve block, and aspirating pleural blood and air that might be limiting lung expansion. The cough reflex was not suppressed by morphia nor was the chest wall motion restricted by tight strapping. By these measures the wet massive collapse of the lung seen in World War I was practically unknown.

The use of a gaseous medium under tension as an extrinsic means of applying increased pressure to support the capillary wall provides the theoretical basis for administering oxygen under pressure in the treatment of irritant gas poisoning and other forms of generalized pulmonary edema as recommended by Barach. The intrinsic mechanism was forecast by Keith in 1909[3] and also by Miller,[4] who stated that, "the action of the bronchial musculature in expiration is not passive, but active, and its action in regulating the tensions within air sacs deserves more attention than physiologists have given to it." Surgeons who work daily with the human lung are well aware of the seeming vagaries of lobular and segmental inflation and deflation. Local reflex changes in circulation that are commonly observed in the abdominal viscera as a result of manipulation and exposure are not discernible in the lung. It is possible that the commonplace local changes in ventilation may have a similar origin and significance. Again, the experienced thoracic surgeon holds great concern for the immediate restoration of the cough reflex after it has been temporarily suspended by anesthesia. This is usually rationalized on the basis of clearing the major air passages. Perhaps it is equally important in the protection of traumatized lobules from the hazards of posttraumatic edema.

The level of action for these mechanisms that integrate ventilation and alveolar air tension, and that I suggest are available for edema control, seems to be at the bronchiole and respiratory bronchiole, the site of the sphincters around the necks of the air sacs. The character of the epithelium has already changed before this point is reached and goblet cells have disappeared. At the level of the segmental bronchus, however, the secreting membrane of the respiratory tract is well developed and introduces a factor in obstruction of the air passages that does not occur at the bronchiolar level. Obstruction of the segmental bronchus is followed by retrograde filling or drowning of the bronchioles and air sacs by the pent-up secretions. In the absence of infection this appears to be a relatively benign event. Accurate observations are not available, but presumably water and salts may be removed by the blood capillaries and protein by the lymphatic channels. The lumens of these obstructed small bronchi become filled by cylindrical casts of a tough rubbery substance. The situation is revealed in the pathologic findings of mucoceles and certain cysts but will not be explored at this time. However, certain physiologic and pathologic implications of the secretory activity of the bronchial mucous membrane deserve brief comment if only to display our present state of ignorance concerning them.

As an example, consider the enigma of the so-called Kartagener syndrome-bronchiectasis, situs inversus, and agenesis of the accessory sinuses. The pathogenesis of the bronchiectasis component has always been baffling. When Adams and I[5] tried to develop a hypothesis some years ago we could only postulate as others had done, that the bronchiectasis was a stigma of maldevelopment. Whether the maldevelopment was structural or took the form of some obscure predisposition to bronchiectasis could not be determined. It was pointed out, however, that the bronchiectasis itself took the form of the acquired rather than the congenital type. Since that time I have had the opportunity of observing two children with situs inversus and agenesis of the sinuses but without bronchiectasis demonstrable in complete series of bronchograms. Both children displayed an extraordinary increase in the secretory activity of the mucous membrane of the respiratory tract. This was manifested by the production of large quantities of mucous secretions both by cough and profuse nasal discharge. The content of pus was minimal. Both children had been born in the chemotherapeutic era of medicine and both had enjoyed the protective concern of well-to-do families able to provide winters in the southwest under able medical surveillance. Threatened episodes of respiratory infection had been handled by preventive measures including chemotherapy and careful observation for collapse and reexpansion of segments. The stage was set for the development of segmental or lobar bronchiectasis but as yet it had not appeared.

In the light of these observations a careful review of the childhood experience of an intelligent young man with the Kartagener syndrome, including bilateral basal bronchiectasis, brought forth a reconstruction of events that paralleled the story of the two children. The profuse mucoid secretion in his case became purulent only after an attack of bronchitis at the age of 14.

It seems, therefore, that the bronchiectasis of the Kartagener trilogy is a secondary manifestation and that the underlying disturbance may be an altered secretory activity of the respiratory tract epithelium.

Recently Bergstrom, Cook, and Scannell[6] have assembled a family history that not only confirms but throws added light on the subject. In this family the bronchiectasis, or as has been proposed the abnormality of the respiratory tract epithelium that precedes it, occurs in two siblings with situs inversus and in two others without situs inversus. Whether the stigma that affects the mucous membrane has a structural basis, a metabolic basis, or is attributable to some derangement of the neurosecretory mechanism, remains unknown. The question as to whether the respiratory mucous membrane behaves as a single organ in its secretory activity or whether lobar or segmental regional autonomy of control may exist also remains unanswered.

Returning to the pulmonary circulation, I remind you that many studies on minor pulmonary embolism that are now classics have demonstrated a collateral drift of blood in the pulmonary capillary network sufficient to maintain a slowly moving circulation despite occlusion of sizable terminals of the pulmonary artery. Increased back pressure in the pulmonary veins or abnormal slowing of the capillary stream by reduced respiratory excursion may convert a bland infarct into a hemorrhagic infarct. It is likely that this capillary blood drift crosses segmental boundaries. In the immediate situation imposed by the embolism, this drift of blood has no respiratory significance; having passed through functioning alveoli, the drifting blood is arterialized and not mixed venous blood. It may help maintain the integrity of the capillary wall, although there is some appearance of edema even in bland infarction, despite the fact that alveolar ventilation continues.

With the vast margin of safety provided the respiratory organs, the functional loss of a few lobules or even segments might seem to be unimportant. There is some evidence, however, to show that the lodgment of minute emboli of cells and agglomerations of tissue debris in the lesser circulation may be such a common event that it can be regarded as a physiologic happening. If this is so, the margin of safety would soon be used up if minor embolism in the terminal arteries always spelled hemorrhagic infarction. The healing process would reduce such an occluded area to a thin plate of fibrous tissue. A series of healed hemorrhagic infarctions thus would cause the remainder of the pulmonary tissue to distend with the changes of complementary emphysema and a concomitant reduction in functional capacity. The limited damage that attends bland infarction, in contrast, does not reduce the volume of the lung.

While the loss of a few square meters of diffusion surface from the 140 with which the lung is equipped for its primary function of respiration might be insignificant, the lung appears designed to conserve a *space-occupying* function. This is true even though the respiratory function of a segment is destroyed. It is observed in the series of events that follows bland infarction with the collateral drift of capillary blood. The same preservation of lung volume apparently to occupy space is also provided for by collateral air drift, as will now be shown.

After the demonstration of Van Allen and Lindskog[7] it was expected to find many instances where collateral respiration came into play in conjunction with pathologic lesions of the lung. However, both the original experiments and the postulated situations in which the drift of air might serve a useful function seemed to characterize collateral air drift as an emergency device. The reason it is not seen more commonly is that segmental bronchial obstruction at levels chosen for experimental demonstration and as observed with tumors, strictures, and foreign bodies takes place in the secretory zone of the respiratory tract epithelium. As a result, maintenance of air in the affected alveoli by passage through collateral channels soon is masked by the drowning of those alveoli with retained secretions. One must descend below the mucous cells to the finer ramifications of the air passages to find an example of collateral air drift at play. The example I shall provide is not protective in the sense of maintaining gas exchange function; it does act to conserve what I have referred to as the space-occupying function of pulmonary tissue that protects the remainder of the lung from complementary emphysema.

In describing the techniques of resection of a pulmonary segment,[8] reference was made to identification of the boundaries of a segment by deflating the lobe, clamping the segmental bronchus, and then inflating the lobe. The segment remains deflated. This is readily demonstrated in a normal lung and holds true with certain forms of bronchiectasis. After further study, however, it was apparent that only in the exceptional cases can this procedure be utilized. Either the segment under consideration is airless and shows the fibrotic changes of long-standing inflammation that preclude inflation, or the segment does not deflate when the endobronchial air pressure is reduced. Indeed, certain of these segments do not deflate when removed from the body and left with widely open bronchial apertures. The air in the alveoli is trapped air. It then occurred to us that bronchography not infrequently shows dilated bronchi extending into air-containing lung segments, but never with lipiodol entering the atria and alveoli. The dilated bronchi resemble the branches of a sea sponge known as "dead-man's-fingers" *(Chalina arbuscula)* and extend into a zone of radiant, air-containing parenchyma but in no way communicate with it. Other observers had commented on this phenomenon and referred to such bronchi as "leafless trees." Robert Klopstock was working with me at the time these observations were made, and using the techniques of Van Allen and Lindskog it was not difficult to demonstrate that the imprisoned air entered or escaped from the area either by way of an adjacent segment with normal bronchi or from an occasional normal branch bronchus within the segment. By more careful preoperative fluoroscopic examination it was possible to confirm the fact that the air in such a segment was indeed trapped exactly as in obstructive emphysema. From the standpoint of gas exchange, this area of lung is devoid of function. The air that reaches the alveoli within it has already passed through other alveoli and reached equilibrium with the pulmonary capillary blood. The air-containing segments are simply filling space. But this, as has been suggested, may have a functional significance.

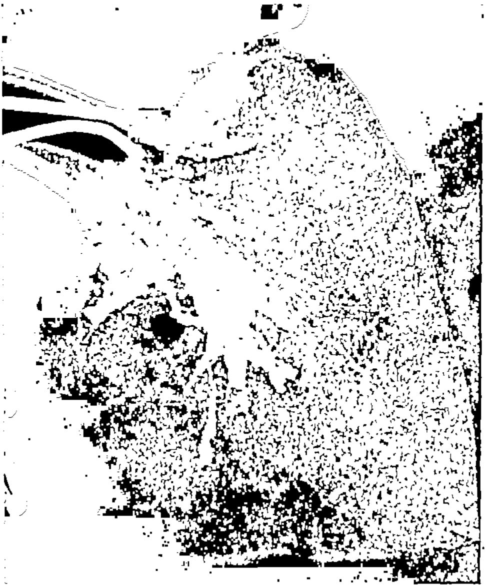


Fig. 4.

Klopstock studied these surgically removed lobes with lipiodol injections of the bronchi, correlating the observations with those made at operation and those made with air-flow techniques. Brief reference is made to three examples, using soft tissue roentgenograms as records.

Fig. 4 records the lipiodol injection of the air passages of a lobe excised from a 23-year-old man with bronchiectasis dating to attacks of pneumonia in early childhood. When the chest was opened the right lower lobe appeared emphysematous but with little or no deformity in its architecture. The dorsal segment deflated when the endotracheal pressure was reduced and inflated when it was elevated. The basal segments could not be deflated. The air that filled their alveoli was trapped, having entered through collateral channels by way of the dorsal segment. The lipiodol filling showed no communication between the dilated bronchi of the basal segments and the surrounding alveoli of those segments.

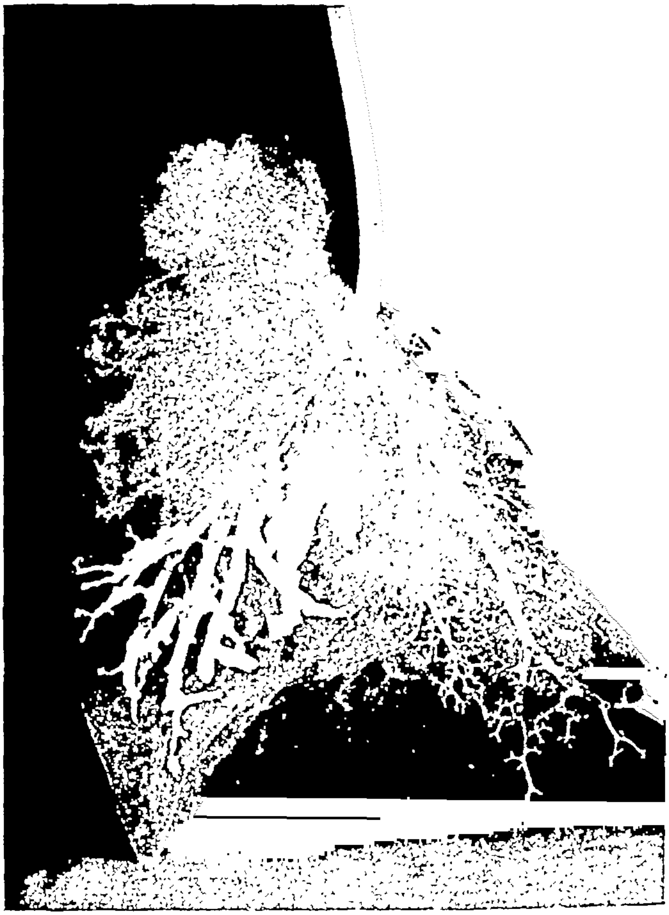


Fig. 5.

This specimen showed, in addition, a phenomenon that is quite constant and that provides further confirmation. The dorsal segment displayed the usual pattern of anthracotic pigmentation, but this was entirely lacking in the basal segments. It is understandable that airborne particulate matter cannot traverse the tortuous channels of the air-drift filter.

As an example of a more complex situation, reference is made to the lower lobe of a young adult woman (Fig. 5). The dorsal segment is not injected in this surgical specimen. It still contains a cloud of alveolar lipiodol from the preoperative bronchogram showing normal air sac filling. One of the three basal segments appears normal, one is grossly bronchiectatic, and one shows a cylindrical enlargement of the bronchi. In only one or two areas of the segment containing the cylindrically dilated bronchi do flecks of alveolar filling appear. All of these segments were found symmetrically distended with air when exposed at operation, in fact, architecturally the lobe appeared completely normal. The affected segments were being maintained in an inflated form by collateral air drift from the adjacent normal segments.

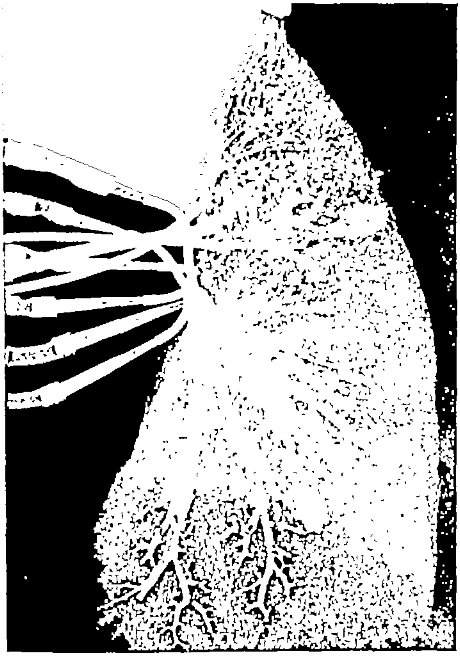


Fig. 6.

From the gross bronchiectasis displayed in these specimens, one may proceed to the state of affairs in the lobe shown in Fig. 6. This is the surgical specimen from an older woman, aged 56 years. Two bouts of pneumonia had been localized to this lobe, then ensued cough, continuing slight fever, lassitude, and disability. This patient was treated for many months with rest, chemotherapy, and climatic change but without improvement. The dorsal segment shows normal alveolar filling. In the basal segments there are a few areas in which the lipiodol enters the alveoli, but in general it is the picture of the "leafless tree," particularly in the mesial segment. There is little deformity that can be termed dilatation of the bronchi, and in fact it is a misnomer to classify this disease as bronchiectasis. The significant lesion appears to be *obliterative bronchitis* and *bronchiolitis.*

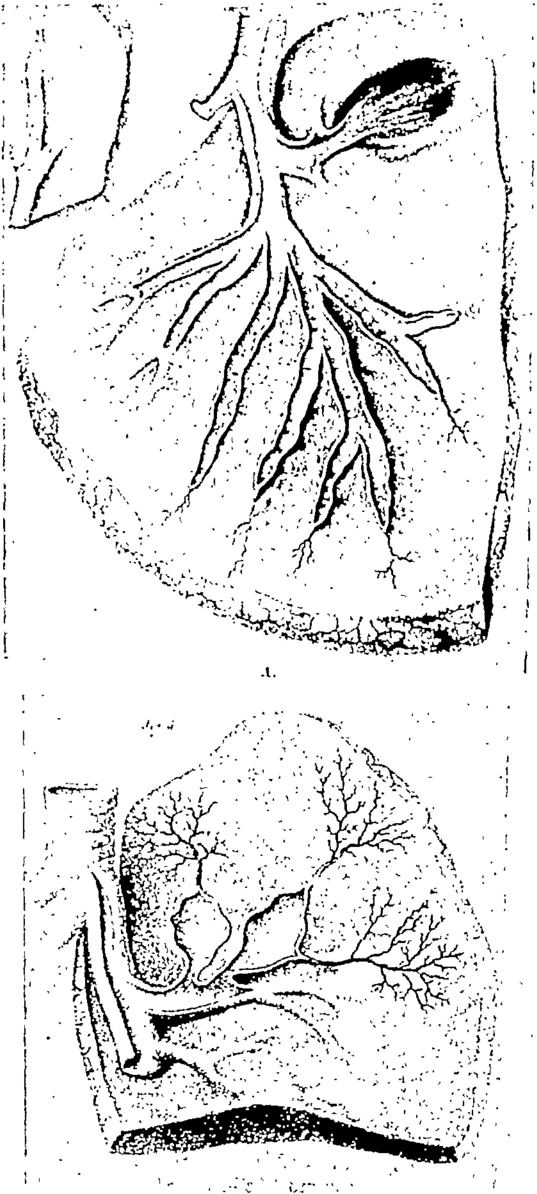
As shown in the preceding illustration this process may exist in one segment and true bronchiectasis in another. In some cases, as those described by Blades[9] as pseudobronchiectasis following virus infection, the obliteration appears to be temporary; in others, when the finer air passages are converted into fibrous cords, it is permanent.

For an adequate description of the morbid anatomy of the changes in the air passages that have been presented, one may go back to 1835.[10] This was the era when lungs were carefully examined in their three dimensional aspects and not chopped up into limp fragments for two dimensional cellular microscopy. In these old illustrations (Fig. 7) of bronchiectatic lobes, the bronchioles and presumably the smaller bronchi are shown reduced to fibrous cords that can be traced to the proximity of the visceral pleura. Observations regarding the state of the surrounding alveoli were not recorded.

I cannot agree with Fleischner[11] that this represents a *preatelectatic* phase in the development of bronchiectasis, although this could be true if the obliterative fibrosis of the bronchi and bronchioles progressed to involve all segments of a lobe. It appears, on the contrary, to represent a static phase of what may initially have been an acute inflammatory process that destroyed and obliterated the finer air passages. It might actually represent a *postatelectatic* phase, if collateral air drift penetrates an area that was atelectatic during the acute phase of infection.

As I have implied, there are, of course, other forms of bronchiectasis in which small dilatations and herniations of the bronchial wall can be traced in the finest bronchial twigs and even in the bronchioles. There are other more common types where inflammation and fibrosis have destroyed the architecture of the air sacs and bronchioles, and converted the lung or a portion of it into an airless, solid organ in which the mechanism of collateral air drift has been forever lost.

Obliterative bronchitis and bronchiolitis with or without atelectasis may be significant in the development of certain types of bronchiectasis and not merely be a by-product of the pathologic process. As a primary lesion it would favor the retention of secretion in the larger bronchi and possibly promote the atrophy of disuse. Basic to an understanding of obliterative disease in the finer air passages is a recognition that their lining membranes are very different from those of the larger divisions. They have a serous rather than mucous secretion. Thus, it is possible for the flames of infection to sweep across the lung and produce permanently obliterated bronchioles without evidence of collapse or fibrosis that is discernible on the x-ray film. Recent studies on lung function tend to confirm this statement.



A.

B.

Fig. 7.

Both capillary blood drift and interalveolar air drift are phenomena unique to this organ. Respiratory function depends on ventilation, not on alveoli containing air; it depends on an active capillary circulation, not on capillaries containing blood. Air-containing lung with normal pulmonary circulation as well as blood-containing lung with normal ventilation may be ineffective from the standpoint of respiratory exchange when the air has entered by way of adjacent alveoli and the blood has entered after traversing adjacent capillaries.

The structure of the lung appears to maintain its spatial integrity despite serious functional deterioration. Intricate mechanisms exist that act to maintain its volume and shape. It is unlike parenchymal organs that dwindle in size following the obliteration of ductal systems or occlusion of vascular channels. It does not become small with the changes of senile atrophy, in fact, the atrophic changes of the aging process produce quite the opposite result as recognized in senile emphysema. When normal lung is called upon to fill spatial demands the changes of complementary emphysema ensue, presumably with further reduction of the functional margin of safety with which this organ is so liberally provided. A segment of the kidney or the liver may be removed without significant reduction of the function of the part that is left behind. Not so with the lung. Surgical principles of conservation of function thus center in conservation of volume.

The apparent homogeneity of the structure and function of the lungs is highly deceptive. They are not two gas bags suspended in a container. Morphologically and functionally the lungs are a highly integrated organ system in which the whole must be considered in relation to the parts, and the parts in relation to the whole and to each other. The two lungs, the single lung, the lobes, the bronchopulmonary segment, and the lobules must be studied from this point of view. Only in this manner can the natural laws be disclosed that will ultimately guide pulmonary surgery.

I have made full use of the immunity that a Presidential Address affords to rebuttal and critical discussion. It must be taken for granted that the interrelationships of factual observations that have been presented will be recognized as hypotheses and valued only as such. I shall conclude with the expression of a conviction that is neither a fact nor an hypothesis, but a value judgment. Surgeons who stand on the threshold of the surgery of the lung today will not find prestige and fame in treading the easy pathways that were open to the older members of this Association. We enjoyed for a brief period the heyday of rapid technical development that follows the initial conquest of a new territory. Advance in the surgery of the lung will not be derived from technical experience alone. Anyone who gains the opportunity to operate on enough patients will have had experience, but it does not follow that one learns from it.

The area I have outlined is not only unexplored territory but it is a no man's land. Our allies in the medical sciences seem to have other pressing affairs that occupy their attention today. It is a territory in which surgeons may work but in which every gain must be bitterly fought for; it is remote from the glamour of scialytic lights and the comforts of lucrative trade. Yet in this area and adjacent ones lie the concepts that are essential if further advance in the surgery of the lung is to be realized.

REFERENCES

1. Landis, Eugene M., and Gibbon, John H., Jr.: The Effects of Temperature and of Tissue Pressure on the Movement of Fluid Through the Human Capillary Wall, J. Clin. Investigation 12: 105, 1933.
2. Macklin, Charles Clifford: The Musculature of the Bronchi and Lungs, Physiol. Rev. 9: 1, 1929.
3. Keith, Arthur: The Mechanism of Respiration in Man. Further Advances in Physiology, edited by Leonard Hill, London, 1909, Longmans, Green & Co.
4. Miller, William Snow: The Musculature of the Finer Divisions of the Bronchial Tree and Its Relations to Certain Pathological Conditions, Am. Rev. Tuberc. 5: 689, 1921.
5. Adams, Ralph, and Churchill, Edw. D.: Situs Inversus, Sinusitis, Bronchiectasis—A Report of 5 Cases, Including Frequency Statistics, J. THORACIC SURG. 7: 206, 1937.
6. Bergstrom, William H., Cook, Charles D., and Scannell, J. Gordon: (To be published.)
7. Van Allen, C. M., and Lindskog, G. E.: Collateral Respiration in the Lung. Rôle in Bronchial Obstruction to Prevent Atelectasis and to Restore Patency, Surg., Gynec. & Obst. 53: 16, 1931.

   Van Allen, C. M., Lindskog, G. E., and Richter, H. G.: Collateral Respiration. Transfer of Air Collaterally Between Pulmonary Lobules, J. Clin. Investigation 10: 559, 1931.
8. Churchill, Edw. D., and Belsey, Ronald: Segmental Pneumonectomy in Bronchiectasis. The Lingula Segment of the Left Upper Lobe, Ann. Surg. 109: 481, 1939.
9. Blades, Brian, and Dugan, David J.: Pseudobronchiectasis, J. THORACIC SURG. 13: 40, 1944.
10. Reynaud, A. C.: Mémoire sur l'oblitération des bronches—Mémoires de l'Académie Royale de Médecine, vol. 4, Paris, 1835, Pl. 3 & 5, J. B. Baillière et fils, p. 167.
11. Fleischner, Felix: Pathogenesis of Bronchiectasis, Am. Rev. Tuberc. 42: 297, 1940.

INTRATHORACIC MENINGOCELE

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ALTHOUGH, with increasing experience in dealing with mediastinal tumors, thoracic surgeons are becoming more accurate in their pre-operative diagnoses as to cell type, there is still an element of surprise when the tumor is exposed at operation. Among those tumors which present a degree of uniformity in the x-ray and clinical picture, and thus lend themselves to pre-operative diagnosis, are the intrathoracic neurofibromas. When a mediastinal tumor presents itself as a uniformly opaque, well-defined, rounded or lobulated mass in the posterior mediastinum, a high percentage will prove to be neurofibromas. When, added to this typical x-ray finding, there is the presence of bony absorption of adjacent posterior rib ends and the skin manifestations of neurofibromatosis of von Recklinghausen, one might feel justified in making the diagnosis of mediastinal neurofibroma. However, that even this typical picture may lead one into error is exemplified by the following case reports:

CASE 1.—G. N., a 36-year-old white housewife, mother of four, was admitted to the University of Michigan Hospital on Feb. 23, 1947. She had been well until five years previously when she had been hospitalized, elsewhere, for "pneumonia and pleurisy." A chest x-ray examination of Oct. 27, 1941, revealed a 10 cm. tumor mass in the right apex posteriorly with a destructive process of the second and third vertebral bodies and the posterior aspect of the third rib. There was a sharp scoliosis to the left. A tentative diagnosis of neurofibroma had been made, and she was advised to have it removed. However, she did not seek further medical advice until one year prior to admission when she developed a persistent, nonproductive cough, mild, progressing to moderate, dyspnea and pain over the apex of the right chest.

The physical examination revealed generalized café-au-lait spots, most marked on the back, scoliosis of the upper dorsal spine with convexity to the right and dullness and diminished to absent breath sounds over the upper posterior right chest.

The laboratory studies revealed no abnormalities of the urine or blood. Roentgenograms revealed a huge lobular density of smooth outline occupying the upper two-thirds of the right hemithorax and situated posteriorly. There was deformity of the third rib, with apparent absorption of its posterior end and there were destructive changes of the second and third dorsal vertebrae.

A diagnosis of intrathoracic neurofibroma, possibly with intraspinal extension, was made and operation was performed on March 4, 1947, under intratracheal ether vapor anesthesia. The chest was entered posterolaterally through the bed of the fourth rib. A huge thin-walled cyst was found almost to fill the hemithorax. Aspiration, to facilitate mobilization, revealed clear watery fluid. It was felt that it might represent a pleural inclusion cyst similar to the so-called pericardial celomic cysts. However, further dissection revealed the cyst wall to be continuous with the dura through a defect measuring

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5 by 2 cm. in size, the defect arising as the result of enlargement and coalescence of the intervertebral foramina of D_2 and D_3, absorption of the pedicle of D_3 and erosion of the postero-lateral aspects of the bodies of D_2 and D_3. Through this defect could be seen the spinal cord and, higher in the spinal canal, at about the level of C_7, the inferior aspect of a small intraspinal cyst. The defect was closed by utilizing a portion of the cyst wall or

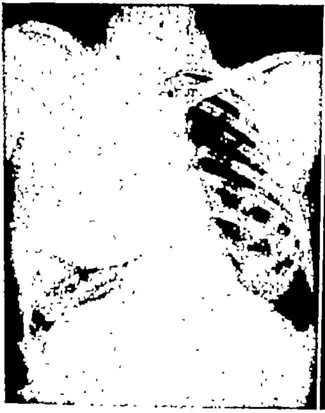

Fig. 1.

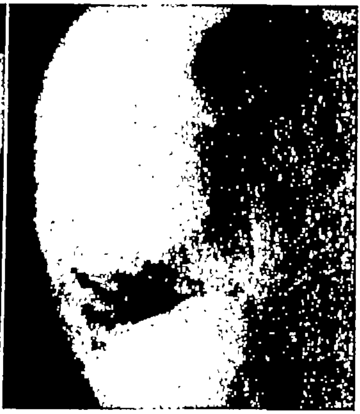

Fig. 2.

Fig. 1 (Case 1).—Preoperative x-ray film showing large intrathoracic mass, scoliosis, rib and vertebral changes.

Fig. 2 (Case 1).—Preoperative lateral film showing posterior location of mass.

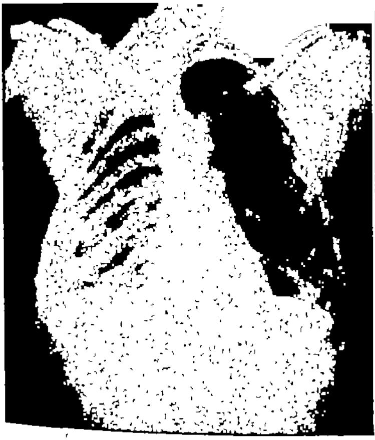

Fig. 3.

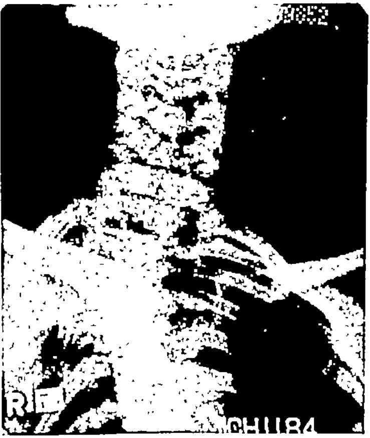

Fig. 4.

Fig. 3 (Case 1).—Chest roentgenogram taken two months after operation.

Fig. 4 (Case 1).—Detail film of apical region to show the upward displacement of rib 2, absorption of posterior end of rib 3, and the absence of rib 4 (excised at operation). The profound destructive changes of the bodies of D_2 and D_3 are shown.

dura as a flap. This was then covered by a free pleural graft and a layer of Gelfoam. Because the upper lobe had been partially collapsed for several years, it did not re-expand readily to fill completely the apex of the chest. An intercostal drainage tube was therefore employed for forty-eight hours.

Postoperatively, the patient experienced mild intermittent headache, relieved by aspirin from the fourth to the ninth days. Her temperature fluctuated from 98° to 102° F. for the first fifteen postoperative days. This was felt to be due to a slow seepage of spinal fluid into the chest. Following her discharge from the hospital, she continued to do well. At the time of her return visit on April 2, 1947, there were no complaints, her temperature had been normal, and the chest roentgenogram revealed that the pleural fluid had been largely absorbed.

CASE 2.—M. A. C., a 21-year-old white soldier had received a gunshot wound of the right arm in 1944, resulting in considerable disability of the arm. There was no injury of the chest or shoulder region. Upon being separated from the service Feb. 5, 1947, a routine chest roentgenogram was obtained which revealed a homogeneous round mass, about 2.5 cm. in diameter, in the apex of the right chest. He was admitted to the Percy Jones General Hospital. For diagnostic purposes a right pneumothorax was induced, revealing the mass to be extrapulmonary. A diagnosis of neurofibroma was made and on Feb. 24, 1947, this mass was explored through a posterior incision, resecting portions of the second and third ribs. The mass was revealed as a cyst, lying extrapleurally with its pedicle in the first interspace. The fluid could be easily expressed but it readily refilled. Ten cubic centimeters of clear fluid were aspirated. The cyst wall was relatively thick. Since it was considered to be a meningocele, was asymptomatic, and in a protected place, it was decided to make no effort to remove it.

Postoperatively, the patient had rather severe headache for several days, relieved by caffeine. After realizing that no demonstrable proof existed to prove this lesion a meningocele, a needle was inserted into the cyst, a small amount of spinal fluid withdrawn and 3 c.c. of Pantopaque injected. The isthmus was not seen fluoroscopically, but the Pantopaque readily entered the spinal canal. Detail films of the upper dorsal region failed to reveal any evidence of vertebral absorption or enlargement of intervertebral foramina.

CASE 3.—J. C., a 61-year-old white man, was admitted to the Letterman General Hospital on June 30, 1947, complaining of severe pain in the cervical region. Intermittent soreness and stiffness of the mid-dorsal region, relieved somewhat by physiotherapy, had been present for about five years. In May, 1946, dull aching pain began to occur in the cervical region. This discomfort was aided by physiotherapy, but one month prior to admission the pain was aggravated by massage. The physical examination revealed many small, soft nodules over the face, arms, legs, and body. Excision of one of these lesions revealed it to be a neurofibroma. There was café-au-lait pigmentation over the flanks and back. The neck was held in flexion with limitation of motion due to pain. A soft mass was present in the right cervical region and this had been present, unchanged, for several years. There was kyphosis of the cervical and upper dorsal spine with scoliosis to the left. Generalized arteriosclerosis was present, and there was a soft apical systolic murmur. The laboratory determinations were not abnormal. Roentgenograms revealed a rounded, well-circumscribed area of increased density, measuring 7 cm. in diameter, situated posteriorly in the right apex. This had remained unchanged for at least two years. No pulsation was present on fluoroscopic examination. The first, second, and third ribs were considerably eroded in their posterior portions with destruction of the heads of the first and second ribs. The first rib was disarticulated and pushed well forward of the transverse process. The right lateral aspect of the body of D_1 and the pedicles of D_1 and D_2 were destroyed. The intervertebral foramina of D_1 and D_2 were enlarged and apparently coalesced. A diagnosis of disseminated neurofibromatosis was made and the mediastinal mass was thought to be an intrathoracic neurofibroma. On Aug. 8, 1947, a right posterolateral thoracotomy was performed, the pleural cavity being entered through the bed of the resected sixth rib. A few adhesions between the mesial portion of the apex and the mediastinal mass were present.

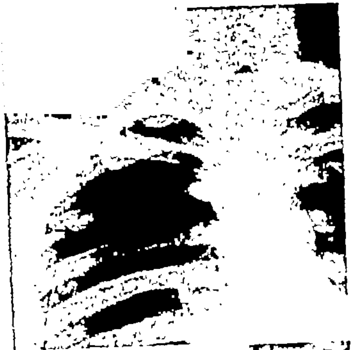

Fig. 5.

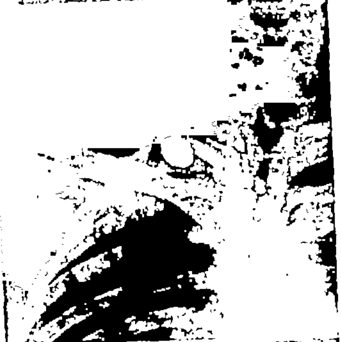

Fig. 6.

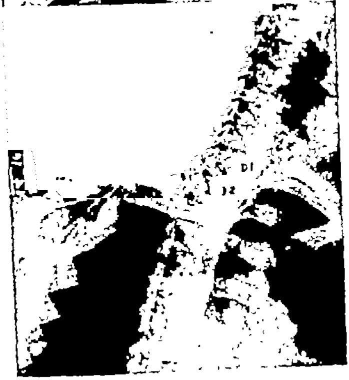

Fig. 7.

Fig. 5 (Case 2).—Film taken after induced pneumothorax. *a* indicates extrapulmonary mass, and *b* the collapsed lung margin. (Figs. 5, 6, and 7 from Sengpiel, G. W., Ruzicka, F. F., and Lodmell, E. A.: Lateral Intrathoracic Meningocele, Radiology 50: 515-520, 1948.)

Fig. 6 (Case 2).—Postoperative film revealing the presence of Pantopaque in the spinal canal following its injection into the cyst.

Fig. 7 (Case 2).—Film taken to outline intervertebral foramina. No enlargement is revealed.

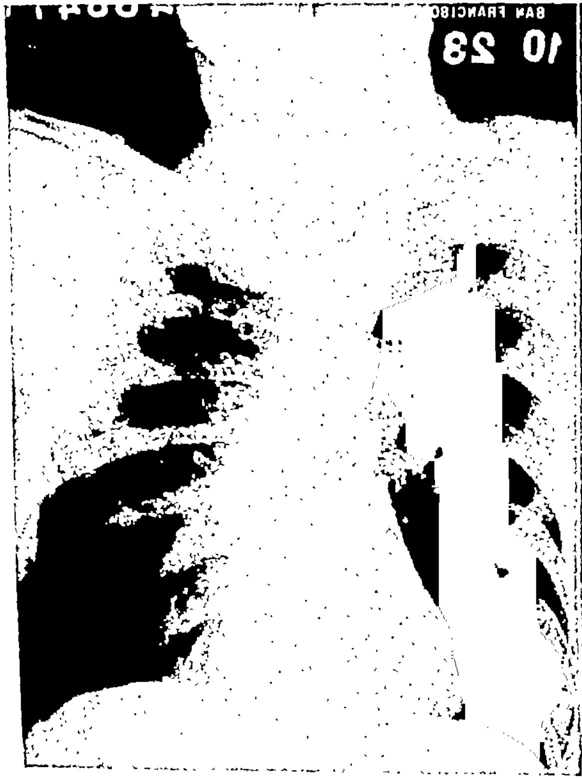

Fig. 8.

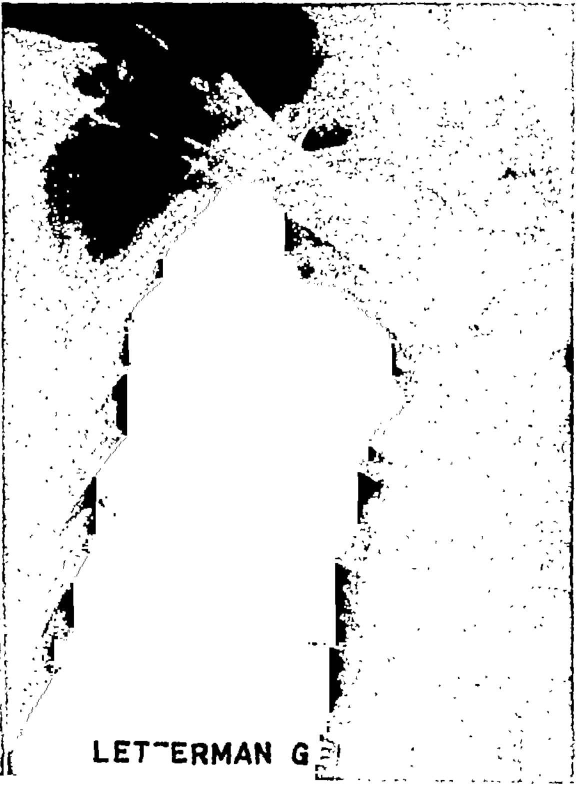

Fig. 9.

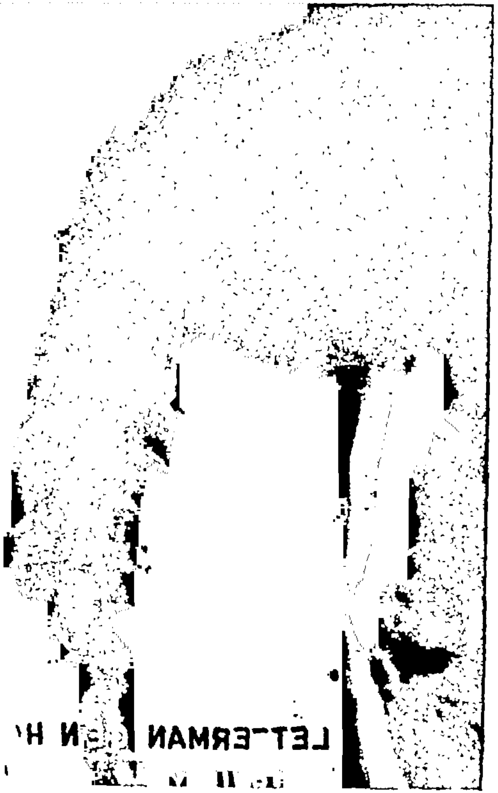

Fig. 10.

Fig. 8 (Case 3).—Frontal projection, showing the round circumscribed density in the cupola of the left thorax, measuring 7 cm. in diameter.

Fig. 9 (Case 3).—Frontal projection, bone detail, showing upper thoracic scoliosis with convexity to left. The posterior portions of the first, second, and third ribs are eroded. The first rib is disarticulated and pushed well forward of the transverse process. The intervertebral foramina of D_1 and D_2 are enlarged.

Fig. 10 (Case 3).—Right lateral projection with contrast barium in esophagus. There is no displacement of esophagus. Posterior position of the rounded mass is shown.

The latter was obviously cystic. The highest intercostal vein was stretched over the cyst. Subpleural dissection, begun posteriorly, resulted in troublesome venous bleeding. Approximately 500 c.c. of blood were lost from this source. The blood pressure fell to 80 mm. Hg, systolic, but the pulse rate remained at 88. The mass was aspirated and colorless fluid obtained. Further dissection of the cyst resulted in recurrence of bleeding and after about ten minutes the pulse and blood pressure could not be obtained. Bleeding was controlled by packing. The heart was stimulated by massage, injection of Adrenalin, and the forced transfusion of 1,500 c.c. of whole blood. There was return of cardiac action, the blood pressure mounting to 190 mm. Hg systolic. Further attempts to enucleate the cyst revealed that, superiorly, portions of the brachial plexus were stretched over the cyst. Fifteen minutes later there was a sudden drop in blood pressure and cardiac arrest. No response occurred to injection of Adrenalin and massage through the opened pericardium.

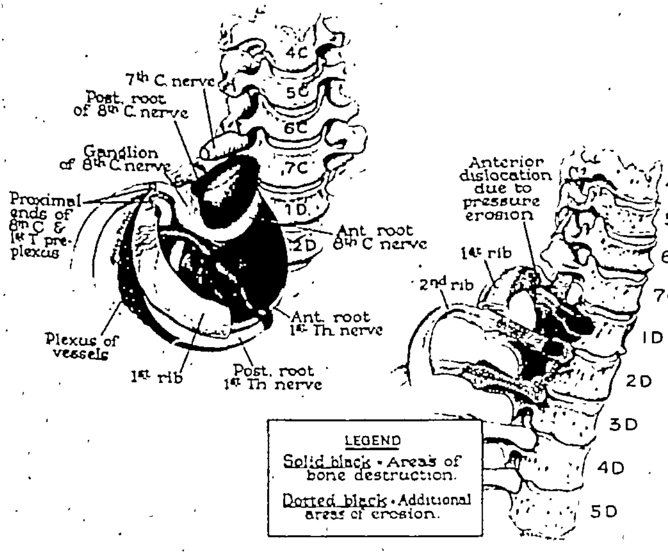
4C
5C
6C
7C
1D
2D
7th C nerve
Post. root of 8th C nerve
Ganglion of 8th C nerve
Proximal ends of 8th C & 1st T pre-plexus
Ant. root 8th C nerve
Ant. root 1st Th nerve
Plexus of vessels
1st rib
Post. root 1st Th nerve
Anterior dislocation due to pressure erosion
1st rib
2nd rib
4C
5C
6C
7C
1D
2D
3D
4D
5D
LEGEND
Solid black - Areas of bone destruction.
Dotted black - Additional areas of erosion.

Fig. 11 (Case 3).—This drawing demonstrates the relationship of the meningocele to first and second ribs, and to the lower trunk of the brachial plexus. The figure to the right shows the extent of bone erosion and bone destruction.

Postmortem examination revealed a tissue-thin meningeal sac projecting extrapleurally through the enlarged intervertebral foramen of C_7. The spinal cord was visible through the opened sac, the wall of which was intimately adherent to the vertebral bodies and the eroded first rib. The spinal cord in this region was diffusely thickened and whitish.*

In 1933, Pohl[1] reported a case of neurofibromatosis with intrathoracic meningocele. The meningocele was excised, the patient dying of empyema. Schuller and Uiberall[2] reported the case of a 56-year-old man who, in 1926, had a diagnosis of neurofibromatosis with intrathoracic tumor. In 1935, the tumor at the level of D_7 to D_9 was described as the size of an apple. Lumbar puncture revealed fluid under normal pressure with a positive Pandy and slight xanthochromia. Lipiodal was injected into the spinal canal and found to enter the tumor. There was evidence of spinal block at D_8. A neurectomy was performed to relieve his pain, but he died following this procedure. The autopsy showed a 10 cm. cyst, absorption of the dorsal surfaces of vertebral bodies D_7 to D_{10}, and an intervertebral foramen large enough to admit two fingers. They had not felt justified in attacking the cyst as Naffziger had warned of the danger of hydrothorax due to drainage of spinal fluid and they further felt that closure of the defect might be difficult. They stress the value of myelography in suspected cases.

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*Complete details of the neuropathologic findings, not germane to this presentation, are being reported elsewhere by Dr. W. H. Garol, Neurosurgical Consultant, and Major H. Sprinz, Chief of Pathology Section, Letterman General Hospital.

Ameuille, Wilmoth, and Kudelski[3] induced a diagnostic pneumothorax in a 46-year-old woman with a large posteriorly located mediastinal tumor. As a further diagnostic procedure, a thoracoscopy was performed and this revealed a large cyst which was translucent, reddish-white, and with numerous vascular arborizations. A diagnosis of hydatid cyst was made and thoracotomy performed. The cyst was found to contain clear fluid. A defect was found in the lateral faces of D_8 and D_9 which seemed to lead into the spinal canal although the spinal cord was not seen. It was not possible to approximate the pleura over the defect. Postoperatively, the patient developed fever, abdominal ascites, urinary retention, and fecal incontinence. The spinal fluid was found to contain staphylococci, and she died on the eighth postoperative day. At autopsy, the chest was found to contain 2,000 c.c. of diluted syrup-colored fluid. The lesion was found to be a dural sac escaping through the defect in the bodies of D_8 and D_9.

Campos[4] reported two cases of what probably represent intrathoracic meningocele, although anatomical confirmation by operation or autopsy is lacking. One was a Brazilian boy, aged 7 years, with the presenting complaint of dorsal scoliosis. X-ray examination revealed a large pedunculated shadow, 5 cm. in diameter, with well-defined margins in the upper right chest. The first six dorsal vertebrae were bifid and there was synostosis of the fourth and fifth dorsal vertebrae. Injection of opaque medium was not employed. The other case was of a 54-year-old Japanese man with symptoms of pericardial pain, dyspnea, and nonproductive cough. A diagnosis of neurofibromatosis was made and confirmed by biopsy of a skin nodule. The chest roentgenogram showed a rounded, well-defined shadow in the right upper chest far posteriorly and an increase in size of the third, fourth, and fifth intervertebral foramina. Penetration was described as occurring through the fifth foramen.

The significance of the fact that neurofibromatosis was present in three of these five reported cases is not clear. Case 1 of this report had café-au-lait spots but no neurofibromas and Case 3 had both. Certainly, it is not of diagnostic aid in differentiating between intrathoracic neurofibroma and intrathoracic meningocele, and, in fact, adds considerable confusion, since one might expect mediastinal neurofibroma as part of the generalized syndrome. Similarly, the rib changes, intervertebral foraminal enlargement, and vertebral body destruction may, and frequently do, occur as a result of neurofibroma. Short of thoracoscopy or thoracotomy, therefore, the only procedure that offers a good chance of differential diagnosis is the intraspinal injection of an opaque medium and positioning of the patient so as to fill, if possible, the suspected meningocele.

The demonstration of a spinal fluid block above the level of the meningocele in the case of Schuller and Uiberall would seem to indicate the presence of an intraspinal lesion, and it will be recalled that in Case 1 of this series a small intraspinal cyst was observed. The simplest explanation of the production of the meningocele itself would seem to be that there is herniation of the dural envelope of a spinal nerve through the intervertebral foramen with pressure necrosis of the vertebral bodies and enlargement of the foramen as the meningocele enlarges. This, however, does not explain the presence of the intraspinal cyst. It seems possible that both the meningocele and intraspinal cysts could have arisen at points of congenital weakness of the dura as in the spinal extradural cysts described by Cloward and Bucy.[5]

Once the diagnosis of intrathoracic meningocele is made, either by demonstrating a communication with the spinal canal or by exploration, the question of the advisability of operation arises. The two patients reported upon by Pohl, Ameuille, and associates, both died of empyema and meningitis, without, of course, the benefit of chemotherapy. In both cases, difficulty was encountered in closing the defect. In our Case 1, a satisfactory closure was also difficult but fortunately seems to have been attained. The dura at the neck of the sac was very thin and of little tensile strength, probably due to stretching by the weight of the cyst. Patients in whom the meningocele has attained such size, as in Case 1 of this report, that respiration is either seriously interfered with, or potentially embarrassed, will require at least partial excision of the meningocele. It would seem advisable to save a generous portion of the neck of the sac so that a plicated closure can be obtained. It is possible that the use of bone grafts to bridge the vertebral or foraminal defect may be feasible. In patients with relatively small sacs, operation is probably not justified unless serial chest roentgenograms reveal progressive enlargement to the point of progressive respiratory embarrassment.

SUMMARY

Three cases of proved intrathoracic meningocele are presented, in one of which excision of the sac with good early recovery was performed.

The literature is reviewed, five previously reported cases being discussed. The two patients in this series on whom excision of the sac was performed both died as a result of empyema and meningitis.

The chief diagnostic aid in differentiating between meningocele and neurofibroma is the intraspinal injection of opaque medium.

The question of advisability of excision of the sac is discussed.

REFERENCES

1. Pohl, R.: Meningocele im Brustraum unter dem Bilde eines intrathorakalen Rundschattens, Röentgenpraxis 5: 747-749, 1933.
2. Schüller, A., and Uiberall, H.: A Case of Neurofibromatosis Recklinghausen Combined With Lateral Spinal Meningocele, Confinia Neurol. 1: 312-317, 1938.
3. Ameuille, P., Wilmoth, P., and Kudelski, C.: Meningocele rachidienne a developpement intrapleural, Bull. et Mem. Soc. méd. d. hôp. de Paris 56: 608-615, 1940.
4. Campos, J. M. Cabello: Meningocele intratoracico, Bol. San. São Lucas 8: 40-48, 1946.
5. Cloward, R. B., and Bucy, P. C.: Spinal Extradural Cysts and Kyphosis Dorsalis Juvenilis, Am. J. Roentgenol. 38: 681-706, 1937.

DISCUSSION

DR. HARVEY J. MENDELSOHN, Cleveland.—I wish to present an additional case of intrathoracic meningocele from Cleveland City Hospital. The patient had been picked up in a routine chest survey by the City Tuberculosis Clinic as having an intrathoracic tumor. She had been asymptomatic until she knew she had this tumor, and she was admitted to the hospital about five months later, at which time she said she had some dyspnea, but on observation in the ward appeared asymptomatic.

(Slides) This shows the tumor in the posteroanterior film, and this shows the posterior position in the lateral film. This patient also had generalized cutaneous neurofibromatosis. Our preoperative diagnosis was mediastinal neurofibroma. However, we suspected some intraspinal involvement. The spinal fluid studies were normal. The patient was explored in August and the defect in the spinal canal can be seen here. We closed it in the same way described by Dr. Byron, by imbricating the sac. We sprinkled some talc in the area. She had an uneventful recovery and was kept in bed for two weeks.

The film one year later showed a normal chest, and the patient is asymptomatic except for a complaint of low back pain.

DR. JEROME R. HEAD, Chicago.—I would like to report an additional case. I believe that the rarity of the condition warrants doing so. The patient was a man, aged 43 years. He entered Hines Veterans Hospital for some other complaint. A routine x-ray film of the chest revealed a globular tumor in the left lower thorax behind the heart. The tumor was directly adjacent to the spine. A needle was inserted into the tumor and crystalline-clear fluid was obtained. Following the aspiration of about 10 c.c. of fluid, the patient developed a typical postlumbar-puncture headache. Several days later a needle was reinserted into the tumor mass and at the same time a needle was inserted into the spinal canal. Withdrawing fluid from the tumor lowered the pressure in the spinal canal, and withdrawing fluid from the spinal canal lowered the pressure in the tumor. The specimens of fluid removed through each needle were comparable in gross appearance, in cell count, and in all chemical analyses. These tests seemed to warrant the diagnosis of intrathoracic meningocele. The patient was not operated upon.

During the preceding discussion concerning the surgery of these meningoceles, the question has been raised concerning the leakage of spinal fluid into the pleural cavity. The following case bears upon this possibility. Some months ago I exposed the stellate ganglion for a vascular surgeon in a case of Raynaud's disease. The exposure was performed in the same manner as an extrapleural pneumothorax. The vascular surgeon then avulsed the sympathetic roots, the rib bed was closed with a running suture, and the wound was closed without drainage. The patient developed a collection of fluid in the extrapleural space. On aspiration this was found to be spinal fluid. Following aspiration of the fluid, the patient developed headache and the fluid rapidly reaccumulated. The question arose as to what to do concerning this complication. We decided to do nothing. The patient had no symptoms referable to the condition and has remained well since.

DR. FRANK S. DOLLEY, Los Angeles.—There are two very important diagnostic symptoms in these cases that Dr. Byron has reported that should be emphasized.

Several years ago, Dr. Brewer and I had published a paper on intrathoracic tumors. In writing of the paravertebral tumors high in the cupola of the hemithorax, we stated that the so-called Pancoast tumor was, in a great majority of cases, actually a primary bronchiogenic carcinoma, having its origin close to the visceral pleura against the mediastinum. We showed that there are a number of other conditions which may cause this paravertebral or paramediastinal shadow, particularly fibromyxoma that would be operable and early fibromyxosarcoma that might also prove to be operable. We did not, however, mention meningocele. This manifestly should be included in this group.

The second point for emphasis is a question of bone erosion.

I have been accustomed to believe that any sign of bone erosion not due to aneurysm or cold abscess could be considered as representing a malignant process and was inoperable.

It is most interesting to me to learn that two of these cases of Dr. Byron's this morning show widespread evidence of bone erosion. The only explanation which occurs to me is that the same sort of mechanism is taking place in these cases as in aneurysm; that is, the meninges themselves do not readily stretch; and the increased pressure against the bone contiguous to the meninges in a situation that does not permit lateral expansion results in bone erosion. Therefore we certainly are not justified, if aneurysm or cold abscess can be eliminated, in looking upon the condition where bone erosion exists as surely malignant and inoperable.

DR. CIAGLIA, Utica, N. Y.—I had no intention of presenting this case but the features were so similar to the ones presented that I thought a few words on it might be in order. This patient was a 31-year-old white woman, who was minding her own business working in a mill, when someone did a survey, and a tumor was reported. She was completely asymptomatic. She also had clinically multiple neurofibromatosis, later proved by biopsy. She had also bony changes with a slight angular scoliosis in the upper thoracic region. The x-ray examination showed a mass clearly defined and rounded, about the size of an orange, in the left apical region. She was explored transpleurally and much to my surprise the tumor was fluctuant. A needle was put in and a crystal-clear fluid was obtained. Later, on examination of this fluid, it was typical spinal fluid with sugar and chlorides and so forth. The pedicle was ligated where it came from the vertebra in the region of the first and second. Similar plastic repair was done as has been described and the postoperative course was completely uneventful except for a Horner's syndrome of moderate degree.

The woman is back at work and I can see no sign of recurrence so far.

DR. BYRON.—This seems to be one of those entities that appear occasionally; one never hears about them and then one learns of a number of cases all together. For instance, pericardial celomic cysts were unheard of until Dr. Lambert reported a case in 1940. Now we know they are very common, and most of us have seen cases. Intrathoracic meningoceles may be reported with increasing frequency. I think there is some importance in making a preoperative diagnosis, because I do not believe operation is indicated in all cases. In the first place, with a large bony defect, it is questionable in many cases whether the defect can ever be satisfactorily closed, and second, since I believe that the meningocele is a herniation of the dura, I see no reason why herniation cannot recur.

THE USE OF TUBED PEDICLE GRAFTS IN CARCINOMA OF THE UPPER ESOPHAGUS

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BEN EISEMAN, M.D. (BY INVITATION)
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CANCER of the esophagus has long tested the resourcefulness of surgeons and despite a prodigious amount of work and no little ingenuity, the results until very recently have been far from noteworthy. However, the past decade has witnessed very significant successes in the conquest of this formidable disease.

North American surgeons and members of this association in particular have contributed pre-eminently to this progress. Adams and Phemister's[1] successful one-stage resection with esophagogastric anastomosis, the first on this continent, stimulated great interest. The subsequent significant contributions in this field by Eggers,[2] Churchill,[3] Garlock,[4] Ochsner and DeBakey,[5] Rienhoff,[6] and in particular Sweet,[7, 8] are too well known to this group to warrant review. Suffice it to say that few of experience would question the desirability of gastric substitution when esophageal sacrifice is necessary. The stomach has been carried higher and higher into the chest so that Sweet[9] has been able to report recently the very creditable achievement of anastomosing the stomach to the esophagus high in the neck.

Despite the eminently satisfactory results with the esophagogastric procedure in lesions from just above the aorta downward, there is a sizable group of the higher lesions for which in our opinion one-stage resection with esophagogastric anastomosis can never be the procedure of choice. Certain features of carcinoma of the cervical and upper thoracic esophagus appear to us of such importance as to justify the consideration of this lesion separately from carcinoma of the middle and lower third.

Rational cancer surgery unequivocally requires the removal of the entire gland-bearing area of the involved structure and the radical extirpation of the lesion. The requirements of a satisfactory cancer resection are well fulfilled for carcinoma at and below the level of the aortic arch by the procedure of resection and esophagogastrostomy in one stage. Lesions above this inevitably become cervicothoracic problems since from this area the lymph drainage is chiefly to the superior and inferior deep cervical lymph nodes (Fig. 1). This has been well shown by the studies of McGibbon,[10] Sakata,[11] and others. Submucosal infiltration, both upward and downward for great distances, occurs often in esophageal cancers so that one might question the validity of ever limiting the resection to the neck. It would appear illogical to limit the resection of the carcinoma and its regional lymphatics simply because a means of reestablishing the

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physiologic function is easily at hand. As great a boon as the one-stage resection with esophagogastrostomy has been, we doubt that its effectiveness can be extended consistently to lesions well above the arch or into the neck.

A further point of importance in our sector is that unfortunately a significant number of people present themselves with an all too frequently ill-done

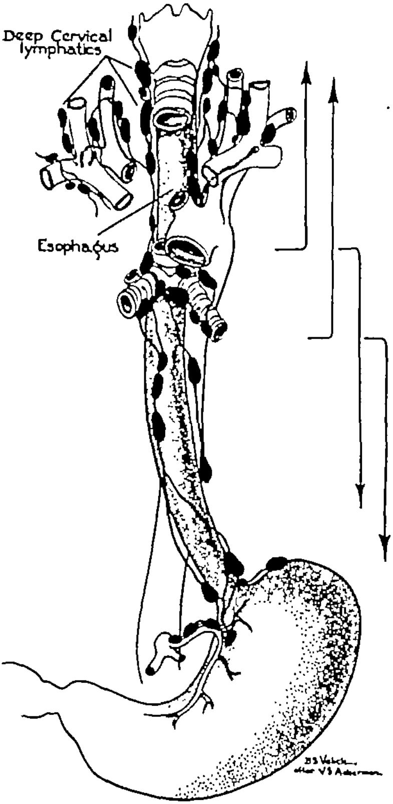

Fig. 1.—The lymph drainage of the upper third of the esophagus is predominantly to the lymph nodes in the lower cervical and supraclavicular region.

gastrostomy. The difficulty or impossibility of elevating such stomachs to the neck or even to the cupola of the thorax is obvious.

It would seem then that a combined cervicothoracic resection with radical resection of the regional cervical lymph nodes bilaterally en bloc would more nearly fulfill the requirements of a satisfactory cancer resection in carcinoma of the upper esophagus. Such a procedure, of course, implies staging, and in this time of enthusiasm for one-stage operations, one can anticipate the criticism leveled at staged procedures. However, this factor can be considered of no more than secondary importance since as Lilienthal[12] so well stated years ago, "The number of operations necessary to accomplish the desired result is of far less importance than its final success."

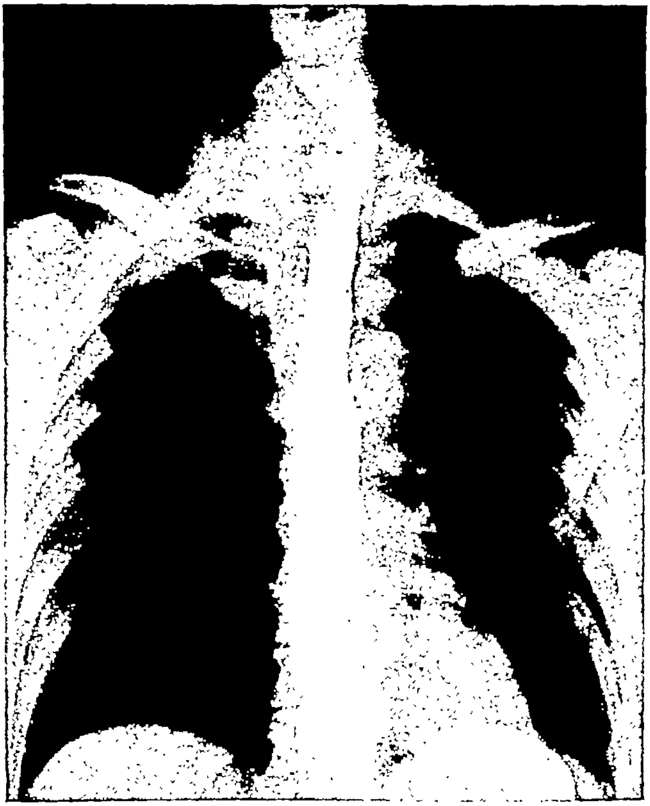

Fig. 2.—Case A. M., showing esophageal defect. The defect and distortion were due to the combined effects of a huge goiter and an annular carcinoma of the esophagus at the level of the first thoracic vertebra.

Struck by the success of Wookey[13] of Canada in the management of carcinoma of the esophagus confined to the upper cervical segment, we decided in 1946 to attempt the incorporation of the principles outlined here into a plan of management for high esophageal lesions. The problem was first approached in the laboratory in the summer of 1946. The first attempts were made toward resection of the esophagus of the dog and immediate replacement with full-thickness free skin grafts. Although free graft was accomplished, the procedure was considered to be of no practical value because of the subsequent contracture of the graft and production of an esophageal obstruction. Attention was then turned toward working out a technique of pedicle graft replacement of the upper portion of the esophagus using a tubed pedicle graft based on the neck and passed through the superior thoracic aperture into the chest for direct anastomosis to the esophagus. Technical difficulties were encountered in the dog which led to the impossibility of always obtaining primary healing and prevented carrying the procedure to completion in a single dog. However, it was learned that long pedicle grafts could be easily prepared and transplanted into the chest and that they could be anastomosed to the esophagus without stricture formation. The technique was developed to such an extent that it was felt justifiable to apply it to a suitable human case. Such a patient was found and is the subject of the following case report.

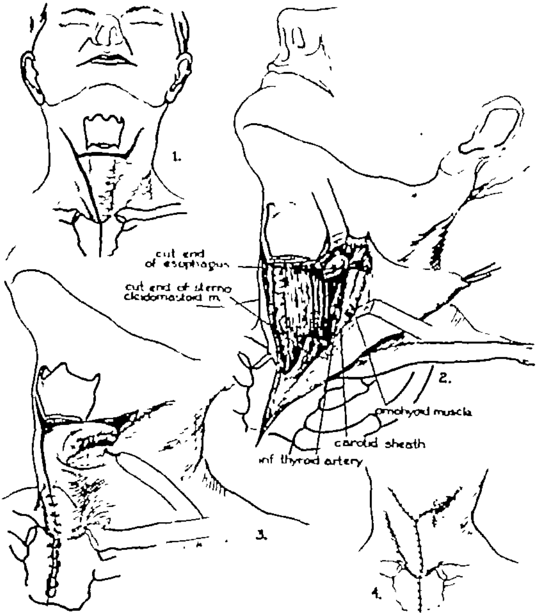

Fig. 3.—The diagrams illustrate the cervical portion of the first stage. This is a combined cervicothoracic procedure, the thoracic exposure being through the right third intercostal space (the same as illustrated in Fig. 5).

The cervical incisions (1) are made in such a way as to turn a triangular flap. The esophagus is amputated high above the lesion at the inferior border of the cricopharyngeus (2) and after the resection the triangular flap is sutured to the cut end of the esophagus (3) in such a manner as to complete the upper end of the esophageal reconstruction.

CASE REPORT

A. M., a 62-year-old white woman, was admitted to the Barnes Hospital on Sept. 2, 1947, with the complaint of difficulty in swallowing for the preceding three months. She had a sensation as if food stopped in the throat at the level of the sternal notch. This difficulty was progressive until at the time of admission she could swallow only liquids and various soft foods. The patient had had enlargement of the thyroid gland since 12 years of age. Ten years before admission she went through a period of nervousness, which was attributed to thyrotoxicosis, and which responded to iodine therapy. She felt that the thyroid gland was larger at the time of this admission than it had ever been before. There had been a weight loss of five pounds in the preceding three months.

The physical examination was not remarkable, except for the presence of the enlarged thyroid, which was about three times its normal size.

X-ray examination of the esophagus revealed displacement of the esophagus to the left and irregular filling, which was considered probably due to pressure from the enlarged thyroid gland. This filling defect started at about the level of the first thoracic vertebra (Fig. 2).

On September 6 an esophagoscopy was performed, at which time a lesion was encountered 18 cm. below the upper alveolar border. This was an annular mass, biopsy of which revealed squamous cell carcinoma, grade III.

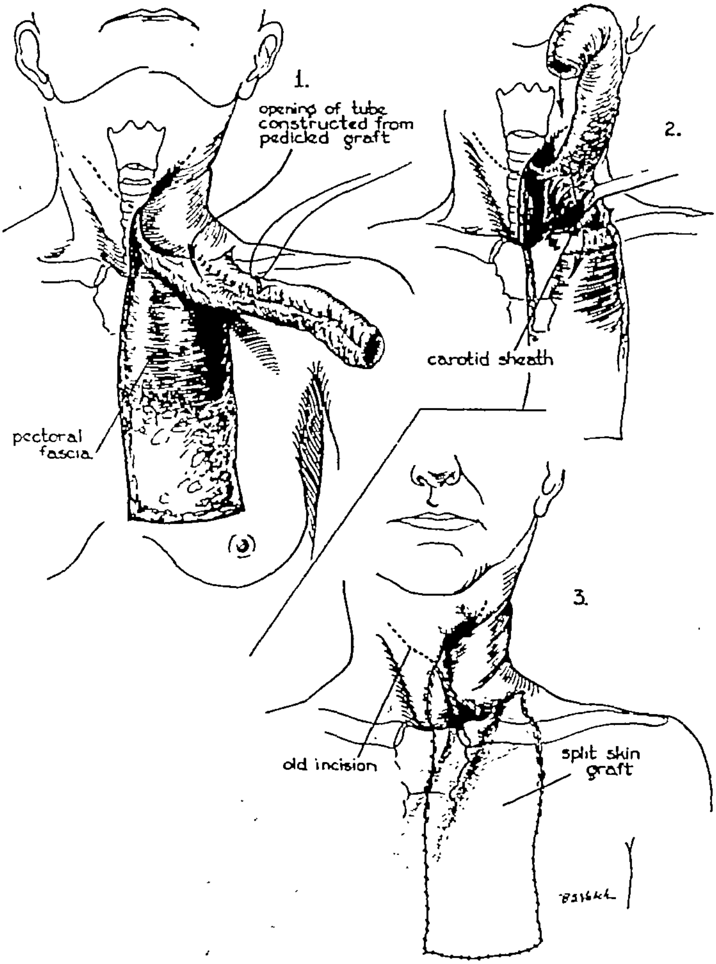

Fig. 4.—After the pedicle graft of the anterior chest wall has been prepared by the usual delaying procedures which insure its blood supply, the graft is converted into a tube (*1*) and passed into the chest medial to the left carotid sheath and posterior to the trachea (*2* and *3*). This procedure again requires a combined cervicothoracic exposure for anastomosis of the graft to the esophageal stump. The donor area from which the pedicle graft was removed is covered with a split-skin graft (*3*).

The patient was carefully evaluated and considered to be a good operative risk. There was no evidence of regional metastasis in the neck. It was decided that a resection of the upper third of the esophagus by a combined cervicothoracic procedure be done, to be followed by reconstruction of the esophagus at a later date. On Sept. 26, 1947, a combined cervicothoracic resection was performed. The right side of the chest was entered through the third intercostal space anteriorly. The lesion was identified with ease slightly above the level of the aortic arch. The esophagus was separated from the vagus nerve and from the trachea, the dissection being carried high into the neck. The tumor was readily palpable and dissected free from surrounding structures. The esophagus was sectioned just below the level of the aortic arch, and the lower end was closed with inverting sutures, then anchored to the prevertebral fascia in order to prevent its retraction downward. The upper end of the esophagus was closed with a ligature, following which the chest incision was approximated and a dressing applied while the attention was turned to the cervical portion of the operation. Incisions were then made in the neck in such a manner as completely to expose the neck anteriorly. A triangular flap was outlined by the incisions as illustrated (Fig. 3). Since the large goiter prevented access to the esophagus, a subtotal thyroidectomy was done, care being taken to protect the recurrent laryngeal nerves. The left sternocleidomastoid muscle was resected, and the contents of the left carotid sheath were retracted laterally. The esophagus was exposed and dissected free of its posterior attachments and of the trachea anteriorly. It was then delivered through the neck after being completely mobilized. The dissection of the esophagus was carried up to the inferior border of the cricopharyngeus muscle at which level it was sectioned. The triangular skin flap was then sutured to the remaining end of the esophagus, and the wound was closed as illustrated (Fig. 3). The thoracic wound was then closed after a catheter had been introduced into the right pleural space for water-seal drainage.

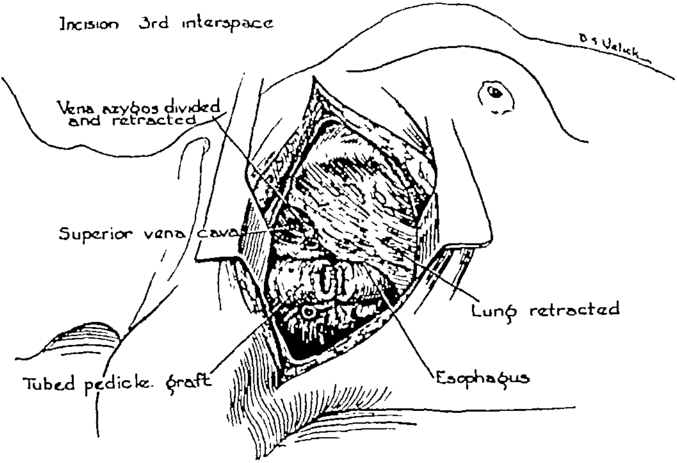

Fig. 5.—The right anterior thoracic approach is again used. It is of the greatest importance that the anastomosis be done meticulously and that perfect primary healing ensue if a stricture is to be prevented.

The postoperative course was uneventful. On Oct. 1, 1947, a Stamm type gastrostomy was done for feeding.

On October 15 the first stage operation for preparing a tubed pedicle graft from the anterior chest wall was performed. Six weeks later the pedicle graft was ready for transplantation into the chest, four minor preparatory procedures having been accomplished in the meantime.

On December 9 the pedicle graft from the anterior chest wall was converted into a tube and inserted into the chest through the superior thoracic aperture and anastomosed to the distal end of the esophagus. This again was a combined cervicothoracic procedure, the thoracic approach to the esophagus being through the right third intercostal space (Figs. 4 and 5). The defect on the anterior chest wall was covered with a split-skin graft.

During the operation biopsies were taken from the neck, from the posterior mediastinum, and from the distal esophageal stump. All of these biopsies subsequently showed what appeared to be a wildly growing anaplastic type of carcinoma.

In view of the positive biopsies, it was decided to give the patient radiation therapy before attempting to complete the esophageal reconstruction. This was done through four posterior thoracic portals, cross-firing the mediastinum; and through two cervical portals, which spared the area which it was hoped might later be used for esophageal reconstruction. The x-ray therapy was started on December 22 and discontinued on Jan. 17, 1948. During this period the patient was fed by a tube through the new esophagostomy opening in the neck, and the gastrostomy was allowed to close.

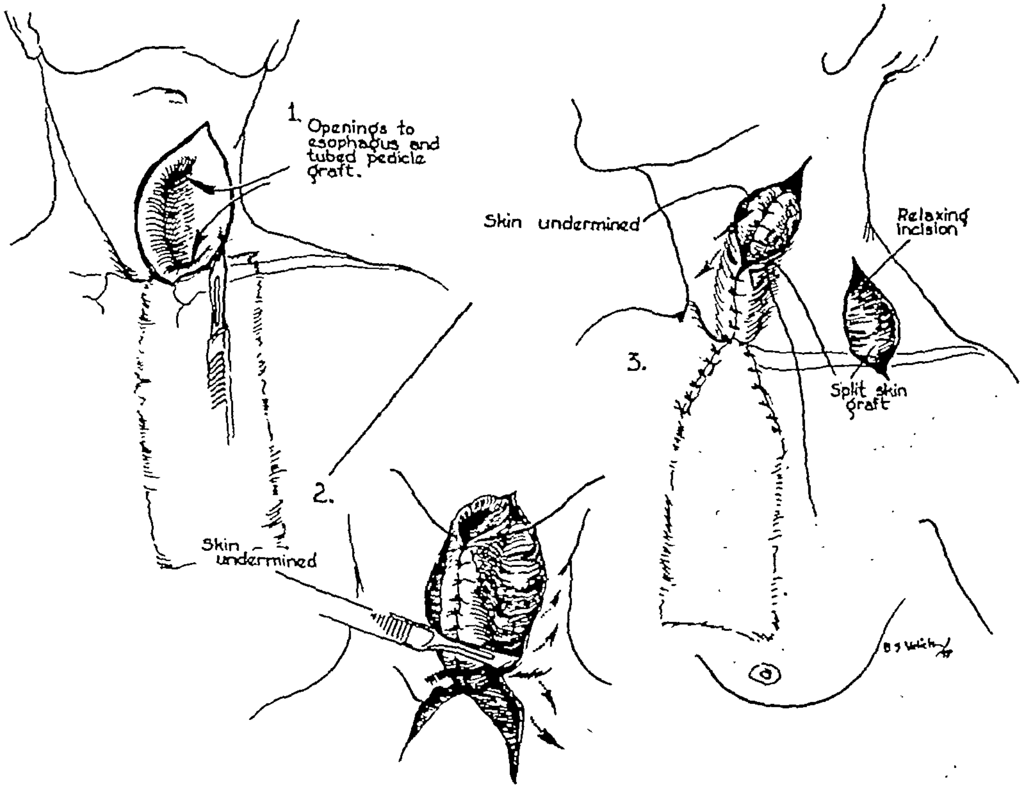

Fig. 6.—The final stage in the reconstruction consists of completing the tube construction in the neck. The upper end of the anastomosis done at the first stage (Fig. 3) is not disturbed. The tube is completed (*1* and *2*), following which the large superficial defect is closed by sliding the skin from both sides and using relaxing incisions as indicated (*3*).

Following subsidence of the radiation reaction, the patient's condition improved markedly, and on March 13, 1948, the cervical portion of the reconstruction was completed (Fig. 6). At the time of this operation some small nodules were encountered deep in the neck which subsequently proved to be carcinoma. The operation was completed in spite of this finding.

The postoperative course was uneventful. The patient was fed through an indwelling tube which had been passed through the nose and into the stomach at the last stage of the reconstruction. This tube was removed on the third postoperative day. Three days later the patient was started on water and liquids by mouth. She could swallow with ease. On the ninth postoperative day she was placed on a soft diet of puréed vegetables, chopped meat, etc., which she took without difficulty. This was rapidly advanced to a regular diet. By the end of two weeks the patient was taking the same diet as other unrestricted patients on the ward. In view of the positive biopsies at the time of the last operation, it was decided again

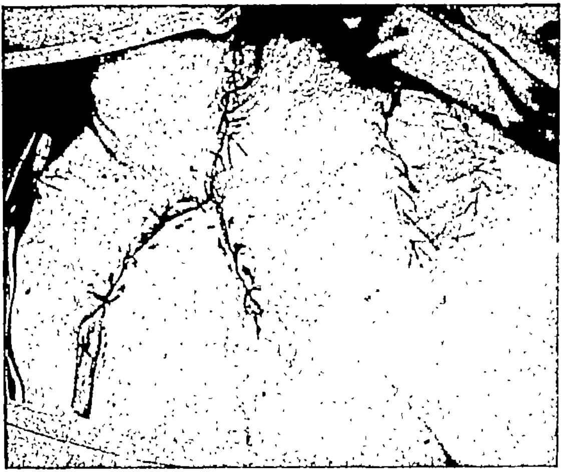

Fig. 7.—The cervical tube is completed and the defect closed. The relaxing incision has been covered with a split-skin graft.

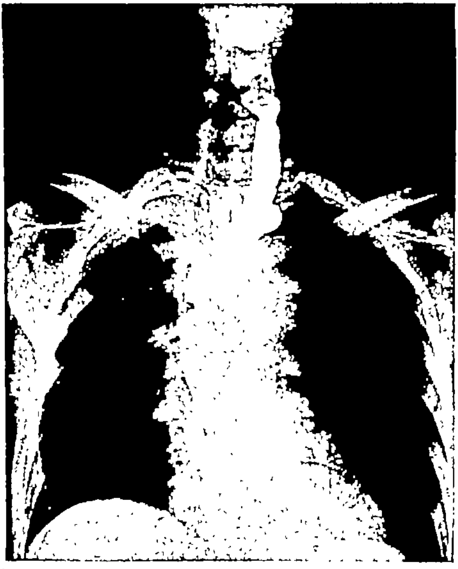

Fig. 8.—Barium swallow x-ray picture taken on the ninth postoperative day. The barium passed promptly into the distal esophagus through wide open stomas at both ends of the inert tube. The swallowing force was good and peristalsis of the distal esophageal segment was present and seemed to have an appreciable effect in emptying the replaced segment.

to administer x-ray therapy. A complete course of radiation was given to the neck through four portals, anterior and posterior and right and left lateral. The patient experienced a severe radiation reaction, and for a while it became difficult for her to swallow. With regression of the reaction, swallowing became better, and at the time of discharge from the hospital on April 30 the patient was again on a normal diet.

Comment.—It is obvious that this patient cannot be expected to be a long survival. The reconstructive procedure was carried to completion in spite of the demonstration of persistent carcinoma. However, at the present time the patient is well and without clinical evidence of recurrence. The operation was complicated by the presence of a large goiter in the neck; consequently, a bilateral neck dissection was not done. We feel that the neck dissection should be an integral part of the procedure, and the technique of this procedure will be the subject of a future presentation.

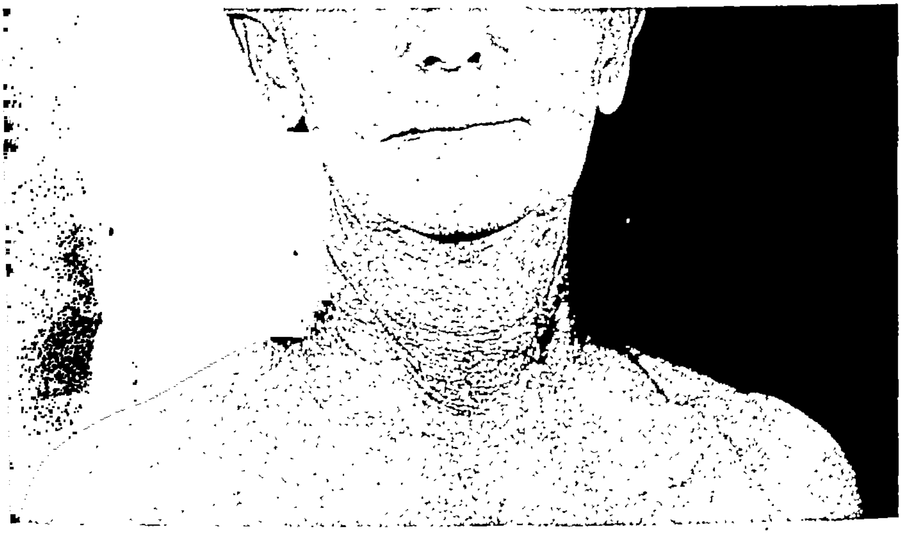

Fig. 9.—Photograph of patient nine months after completion of operation, showing normal appearance of neck and chest wall.

A point of particular interest to us has been the retention of active peristalsis in the distal segment. When a thick barium meal is given, the barium column goes rapidly and readily down to the lower anastomosis site where immediate active peristalsis begins with the result that almost instantaneously the reconstructed portion of the food passage is sucked empty. This, we believe, has very important implications.

DISCUSSION

While such a small experience is never too imposing, we feel justified in reporting it since certain important principles are involved. First, it appears that the rational approach to cancer of the upper third of the esophagus requires resection of the lymph nodes most likely to be involved. Second, a combined cervicothoracic resection and bilateral neck dissection is a feasible procedure, and, in our opinion, a less extensive assault falls short of the modern standards for cancer surgery. Moreover, this experience demonstrates the possibility, for the first time to our knowledge, of utilizing tubed pedicle grafts within the mediastinum. Of the greatest interest perhaps is the highly satisfactory functional result obtained.

We feel that with future cases the time can be greatly shortened so that the entire procedure can be completed within eight to ten weeks.

The applicability of this procedure to high localized strictures of nonneoplastic origin which are not suitable for esophagogastrostomy is, of course, obvious. In such cases the entire procedure can be completed much more quickly.

We wish to stress that in no sense are we unmindful of the magnificent advances stemming from the principles of one-stage resection with esophagogastrostomy. Our hope is that the procedure described here will prove to be a useful addition to the armamentarium of the surgeon in his struggle with cancer of the upper esophagus.

Grateful acknowledgment is made of the valuable advice and criticism we received from the members of the Plastic Surgery Service of Barnes Hospital.

REFERENCES

1. Adams, W. E., and Phemister, D. B.: Carcinoma of Lower Thoracic Esophagus: Report of Successful Resection and Esophagogastrostomy, J. THORACIC SURG. 7: 621, 1938.
2. Eggers, Carl: Treatment of Carcinoma of the Esophagus, Surg., Gynec. & Obst. 63: 54, 1936.
3. Churchill, E. D., and Sweet, R. H.: Transthoracic Resection of Tumors of the Stomach and Esophagus, Ann. Surg. 115: 897, 1942.
4. Garlock, J. H.: Surgical Treatment of Carcinoma of the Esophagus, Arch. Surg. 41: 1184, 1940.
5. Ochsner, A., and DeBakey, M.: Surgical Aspects of Carcinoma of the Esophagus, J. THORACIC SURGERY 10: 401, 1941.
6. Rienhoff, W. F.: Intrathoracic Esophagojejunostomy for Lesions of the Upper Third of the Esophagus, South M. J. 39: 928, 1946.
7. Sweet, R. H.: Carcinoma of the Midthoracic Esophagus; Its Treatment by Radical Resection and High Intrathoracic Esophagogastric Anastomosis, Ann. Surg. 124: 653, 1946.
8. Sweet, R. H.: Carcinoma of the Esophagus and the Cardiac End of the Stomach; Immediate and Late Results of Treatment by Resection and Primary Esophagogastric Anastomosis, J. A. M. A. 135: 485, 1947.
9. Sweet, R. H.: A New Method of Restoring Continuity of the Alimentary Canal in Cases of Congenital Atresia of the Esophagus With Tracheo-Esophageal Fistula not Treated by Primary Anastomosis, Ann. Surg. 127: 757, 1948.
10. McGibbon, J. E. G.: The Clinical Manifestations of the Spread of Carcinoma of the Esophagus Observed During Life, Brit. J. Surg. 24: 86, 1936.
11. Sakata, K.: Ueber die Lymphgefässe des Oesophagus und über Seine Regionären Lymphdrusen mit Berücksichtigung der Verbreitung des Carcinomas, Mitt. a. d. Grenzgeb. d. Med. u. Chir. 11: 634, 1903.
12. Lilienthal, H.: Thoracic Surgery, Vol. I, Philadelphia, 1925, W. B. Saunders Company, p. 328.
13. Wookey, H.: The Surgical Treatment of Carcinoma of the Pharynx and Upper Esophagus, Surg., Gynec. & Obst. 75: 409, 1942.

DISCUSSION

DR. FRANCIS O'DONNELL, Ann Arbor.—We have had an opportunity at the University of Michigan to see a case of the type mentioned by Dr. Burford. We, however, treated it differently. We performed a total esophagectomy, anastomosing the stomach to the pharynx. (Slides.) The patient was admitted in February, 1948, with a six-month history of progressive dysphasia. He had been reduced to a liquid diet for three months. He was in excellent general health. X-ray examination showed a stricture 4 cm. above the suprasternal notch. Esophagoscopy revealed the tumor to lie 3 cm. below the upper end of the esophagus. Biopsy showed a scirrhus carcinoma; there was no evidence of metastases.

The patient refused a flap operation and left the hospital, but returned in two months, having lost thirty pounds and having been completely obstructed for five days. Roentgenogram showed complete obstruction. The stomach was mobilized and brought to the apex of the chest. Of interest is the fact that the stomach was brought behind or to the right side of the arotic arch, since it is found that the esophagus takes the shortest and most direct route. A cervical incision was then made and the thoracic esophagus was brought out through the incision.

The incision on the tenth postoperative day consisted of a transverse incision and extension up the left sternomastoid. The cervical esophagus and the inferior 3 cm. of the pharynx were then freed and, drawing the stomach up into the neck, an anastomosis was made and the esophagus was removed.

(Slide.) This is the resected specimen showing the upper end—the free piece of tissue is the abdominal portion of the esophagus which was removed so that closure of the stomach could be through the gastric wall rather than the esophageal wall. When the anastomosis was performed at the neck there was free bleeding from the stomach, as a quarter size piece of gastric wall was excised preparatory to the anastomosis. Much to the relief of the surgeon, five ligatures had to be placed in the submucosal bleeding vessels of the gastric wall. The chest and neck were both drained. Penicillin was given for twenty days postoperatively and streptomycin for five days. The postoperative course was relatively benign except for a diarrhea on the seventh postoperative day, which might have been foreseen because of the extensive vagus resection. The diarrhea ceased on the thirteenth day.

(Slide.) This shows the thoracic and cervical stomach as seen on the twelfth day. There are two points of interest. On the right side can be seen the pylorus lying about 4 cm. below the diaphragm. The duodenal loop is somewhat straightened because of mobilization of the duodenum and moving it toward the left. At the left can be seen the stomach extending high into the neck, the barium just opposite the hyoid bone. We were unable to time our x-rays to catch the barium as it went through the pharynx and stomach. We had one severe problem postoperatively. There was no inferior constrictor muscle because it was excised. This led to small ulcerations about the mouth. They were treated by giving small amounts of alkali and the head of the bed was elevated to prevent regurgitation. He has gained twelve pounds since operation. Dr. Alexander sent me a wire last night saying the patient's temperature is normal and he is eating very well.

DR. RICHARD H. SWEET, Boston.—I was intensely interested in this presentation and congratulate Dr. Bricker and his associates on the successful accomplishment of something I have had in mind for a long time. I think one of the most significant things is that they lay emphasis in the correct place; we are dealing with a malignant tumor which has probably already metastasized to the regional lymph nodes when the patient comes in for treatment. In other words, any attempt at cure without taking out the regional lymph nodes will be doomed to failure. I have had a great deal of early enthusiasm for Dr. Wookey's procedure, but although I have had great success with function after the procedure—the ultimate result has been disappointing. All patients have died of recurrent or metastatic disease.

(Slides.) If we can relieve the patient so that he can swallow for the rest of his life that is probably all we will accomplish. In this case we were fortunate in catching some of the barium going through the anastomosis.

I think we should try the technique described here, but I am sure in my hands it would be doomed to failure, as was the Wookey procedure, unless we can take out the regional lymph nodes.

DR. JOHN R. PAINE, Buffalo.—I should like to tell of one patient operated upon with minor variations of Dr. Wookey's technique. This was a 53-year-old woman who had been obstructed for three months.

(Slides.) This is the x-ray film taken in 1947 showing the obstruction in the lower portion of the cervical esophagus. We used the Wookey technique, making a flap on the front of the neck. It was excised down to the upper border of the third dorsal vertebra. The larynx was involved in this case. Three biopsies had been reported as negative. At the time of operation the pathologist was willing to say it was a neoplasm, but did not say what the character was.

This picture was made three months later. It is hard to indicate exactly where the anastomosis is. The segment extends from the top of the third dorsal vertebra up to the pharynx. This is the late view after reconstruction of a skin tube. The barium will be seen in the sinus formed after the second operation. Four attempts were made at closure without success, and when the patient came back in one week they had closed of their own accord. After study of the section, several pathologists have told me it is some variety of sarcoma or endothelioma, but they are not definite as to type. Several lymph nodes were reported as negative after removal, and I hope this patient has some chance of cure.

This picture shows a trough through which she swallowed saliva. The second operation bridged this trough over.

DR. BRICKER.—I would like to thank the discussors, and particularly Dr. Sweet, for his encouragement. We are, of course, unable to argue strongly for this procedure on the basis of only one case. However, the enthusiasm which we admit is based on certain points which we think are sound:

First, regarding the cancer resection, we feel that a bilateral neck dissection and en bloc resection of the esophagus is the only procedure that can logically be expected to offer a reasonable chance of cure. Of course, if one decides that the disease is actually incurable, a view not too unjustified by survival figures so far, and that any surgery is simply palliative, aimed at allowing the patient to swallow comfortably for as long as possible, then the neck dissection can be discarded as a useless procedure. However, we disagree with this philosophy and feel that we should continue to aim at curability, and that time will prove that carcinoma of the upper third of the esophagus will not be controlled without regional lymph node removal.

The technique of bilateral neck dissection en bloc with the esophagus is a perfectly feasible procedure anatomically, which we hope to report in detail in the future.

Postericoid and higher lesions can be handled in a similar manner, the technical procedure being somewhat simplified by the sacrifice of the entire ribbon muscle compartment and larynx, with preservation of parathyroid function being the only problem. It is our opinion, admittedly not entirely crystallized at this point, that even the postcoracoid lesion should be handled as a combined cervicothoracic problem. This opinion is based on the necessity for wide resection of the esophagus itself, occasioned by the extensive submucosal lymphatic spread which we have witnessed and which has been noted by others.

Second, regarding restoration of the esophagus, our enthusiasm, which remains still to be justified, stems from the following points, most of which have already been covered.

1. The method provides a means of bridging a gap by choosing the shortest distance between two points.

2. The method provides the only means, to our knowledge, of preserving the propulsive force of the swallowing mechanism, plus the peristaltic force of the distal esophagus, plus a physiologic esophagogastric opening.

3. The method provides for intrathoracic reconstruction with tissue which has been prepared and for which the blood supply has been assured, rather than with tissue, such as jejunum or stomach, which must be carried in a one-stage procedure to the poorly defined limit of its blood supply and viability, and buried from sight.

4. The method does not require the disturbance or displacement of abdominal viscera in any way, except for the performance of a gastrostomy.

TRANSTHORACIC SMALL BOWEL SUBSTITUTION IN HIGH STRICTURE OF THE ESOPHAGUS

Albert Wilson Harrison, M.D.
Galveston, Texas

The construction of an artificial esophagus has challenged the ingenuity of surgeons throughout the world. That this challenge yet remains is testified by the multiplicity of approaches and methods used and by the perennial appearance of new techniques. A comprehensive summary of these techniques was published in 1944 by Yudin[3] of Moscow and his results in an extensive experience with 80 cases reflected the gratifying progress that had been made. Since then Longmire and Ravitch[1] have demonstrated the use of transplanted small bowel within a skin tube and even the preservation of its blood supply by anastomosis to the internal mammary artery. Rienhoff[2] has used small bowel transthoracically by reversing a length of jejunum back into the chest and anastomosing it antiperistaltically with the esophagus.

It is in the hope of contributing a bit further to the solution of this problem that the following cases are reported.

CASE REPORTS

Case 1.—P. H. W. (Fig. 1), a 3-year-old colored boy, had had a Janeway gastrostomy almost two years previously for lye stricture of the esophagus. Investigation revealed the stricture to be practically complete at the level of the cricoid cartilage (Fig. 3) and all attempts at dilatation failed. It was obvious that if he were to eat again, some form of substitution would be necessary. To this end three stages of operation were planned. In the first, through an abdominal incision, a segment of jejunum was prepared with one arcade of blood supply and isolated. Jejunal continuity was re-established by end-to-end anastomosis. The isolated segment was brought up through the transverse mesocolon, its distal end being anastomosed to the fundus of the stomach and its proximal end closed. Two weeks later the left side of the chest and diaphragm were opened. The esophagus was dissected from the mediastinum and transected at the cardia. It was then brought out through an incision in the neck along with the proximal end of the jejunal loop. Excess esophagus was left for a few days to conduct saliva away from the neck wound.

After this stage an unplanned gastroenterostomy became necessary to relieve an obstruction at the pylorus. Apparently this was due to the combined effects of vagotomy and bow-stringing of the artery to the displaced segment across the lower stomach. At the third stage, two weeks following the second, the stricture was excised and the pharynx was opened to a diameter of 1.5 cm. by a posterior median slit. The jejunal segment was opened and a two layer end-to-end anastomosis was made to the pharynx.

A good result was obtained at first. The chest was clear (Fig. 5) and a barium swallow (Fig. 7) passed rapidly into the more tortuous bowel within the chest. Rapid and vigorous peristalsis delivered it into the stomach in less than one minute. Within a few weeks, however, swallowing became more difficult and an attempt at dilatation resulted in a pneumothorax. Four months after the third stage the pharyngojejunal anastomosis was excised and reconstructed with a much larger aperture. This time the child was discharged home, eating normally. He still swallows well four months later.

From the Department of Surgery, University of Texas, Medical Branch.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

CASE 2.—C. B. (Fig. 2), also a 3-year-old colored boy, had had a Janeway gastrostomy after drinking lye at about the age of 16 months. Barium study showed a complete stricture of the esophagus just above the manubrium (Fig. 4). Operation was done in three stages as in the first case, but with certain notable differences. In the first stage the isolated loop was brought up behind the stomach and out through the gastrohepatic omentum, and in the second stage the vagus nerves were carefully preserved. The esophagus itself was unusual in that it had become obliterated and reduced to a fibrous cord in the thoracic inlet. Finally during the dissection it pulled out entirely. An artificial opening was made up through the cervical mediastinum and the end of the loop was implanted alongside the upper esophageal segment. In the third stage the upper esophageal pouch was found to be quite large and filled with wads of chewing gum, food, and other matter. To obtain a sufficiently wide anastomosis here was no problem.

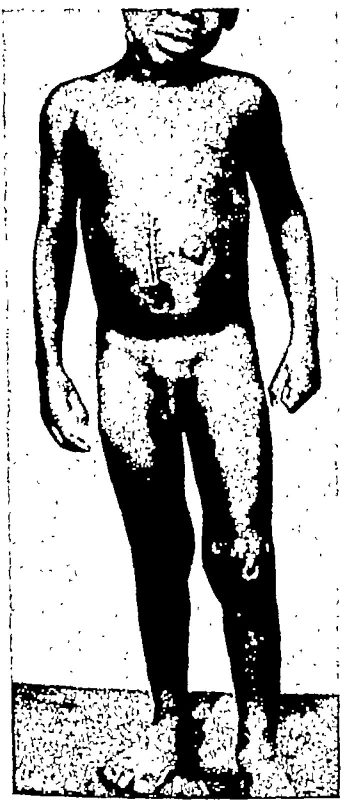

Fig. 1.

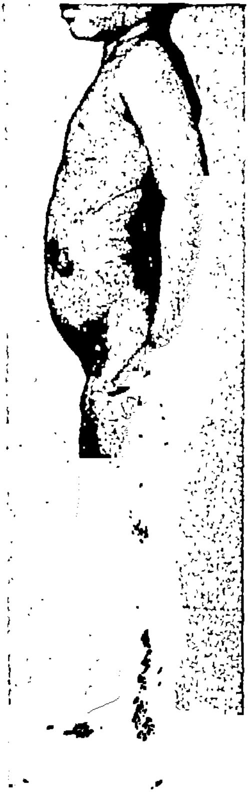

Fig. 2.

Fig. 1 (Case 1).—Photograph showing gastrostomy and scars of the various stages of operation.

Fig. 2 (Case 2).—*Photograph showing* lateral view.

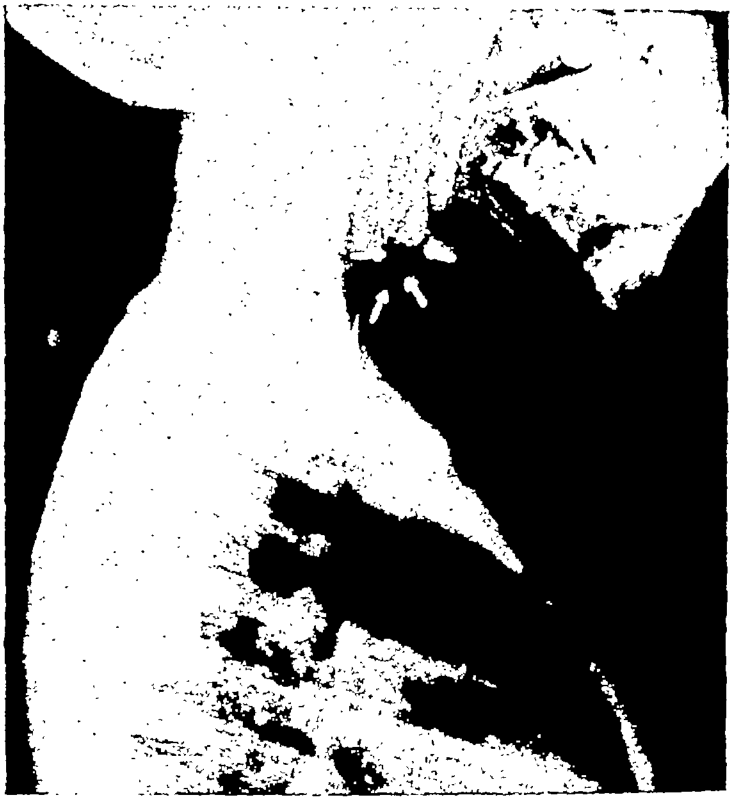

Fig. 3 (Case 1).—Arrows indicate outline of barium above the stricture.

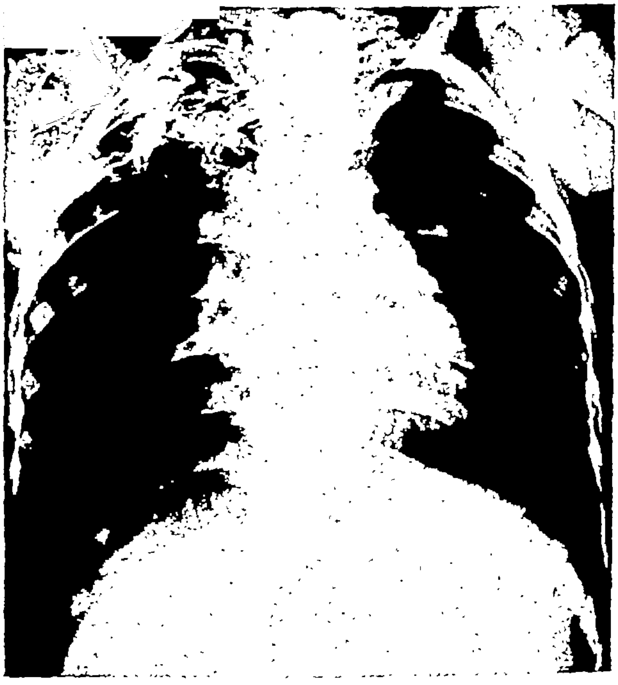

Fig. 4 (Case 2).—Dilated esophageal pouch filled with barium; extraneous barium on skin appears on the right.

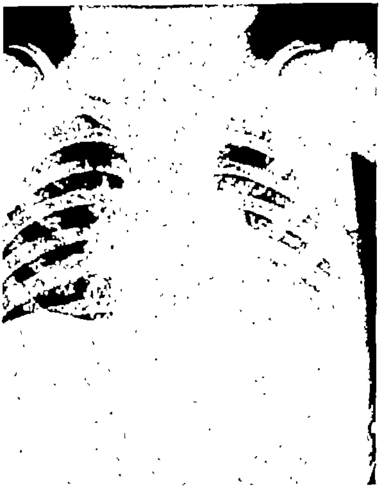

Fig. 5.

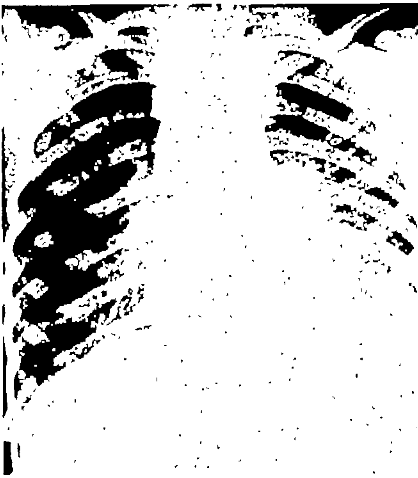

Fig. 6.

Fig. 5 (Case 1).—Postoperative chest film of patient showing dilated stomach.
Fig. 6 (Case 2).—Postoperative chest film of patient, relatively clear.

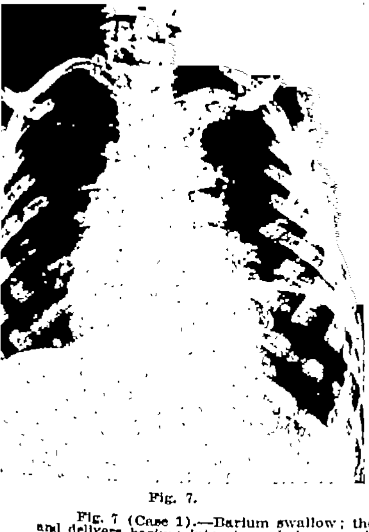

Fig. 7.

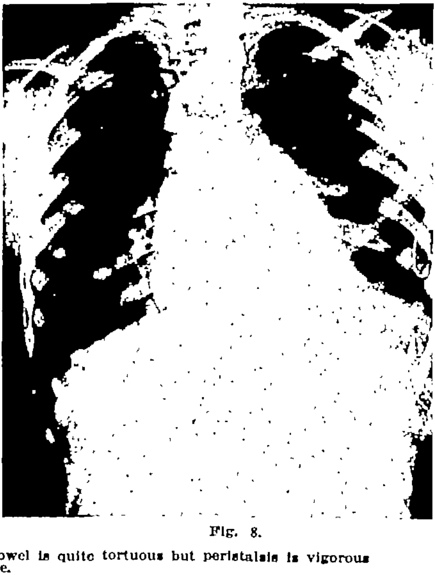

Fig. 8.

Fig. 7 (Case 1).—Barium swallow; the bowel is quite tortuous but peristalsis is vigorous and delivers barium into stomach in one minute.

Fig. 8 (Case 2).—Barium swallow, showing straighter bowel and more rapid progress of barium.

Postoperatively the chest was clear (Fig. 6) and the barium swallow (Figs. 8 and 9) dropped more or less straight to the lower thorax where peristalsis in the lower coils rapidly passed it on into the stomach. The patient was discharged in one month after operation, eating normally. Plans were to leave the gastrostomy open for a test period of one year or so before closure.

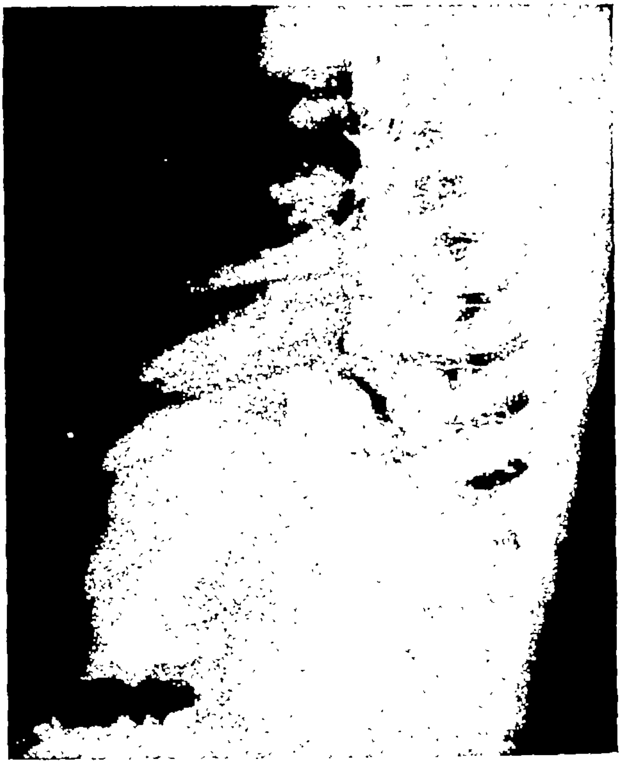

Fig. 9 (Case 2).—Lateral view showing bowel fairly straight in upper mediastinum, coiled in lower.

From these histories it is evident that three principal mistakes were made in the first case. (1) The antegastric transposition of the jejunal segment resulted in obstruction in the antral region of the stomach. (2) Vagotomy at the time the esophagus was resected rendered the stomach atonic and contributed to the obstruction. (3) The anastomosis at the pharyngeal junction was made too small because of fear of interfering with the mechanics of swallowing, whereas subsequent observation showed this danger to be more theoretic than real. There were no significant complications other than the ones mentioned. The thoracic duct fortunately was not encountered in either case and the recurrent laryngeal nerves were carefully avoided. The distal esophagus was resected both times to eliminate a potential source of danger in the mediastinum. All wounds healed per primam.

TECHNIQUE

The problem in the first stage of such an operation is to isolate a segment of jejunum whose blood supply will have adequate length to reach the neck without undue tension and without too much redundancy of bowel. To accomplish this a long arterial arcade is established by sacrificing as many intermediate radicals as seems necessary (Fig. 10), usually no more than one or two main jejunal branches. As shown in the drawings, the bowel is transected proximally where the secondary radicals are longest so as to give maximal upward offset of bowel along blood supply, thereby adding length to the proximal end. The distal end on the other hand should be cut as short as blood supply to the remaining jejunum will permit. This serves to minimize redundancy in the isolated segment, which is always a problem. The proximal arterial supply is not divided as in the drawing until the second stage.

The loop is brought up through the transverse mesocolon, the lesser peritoneal sac, and the gastrohepatic omentum where it is fixed to preserve maximum length above this structure. The proximal arterial radical is tagged for ready identification later. The continuity of the remaining jejunum is re-established by end-to-end anastomosis.

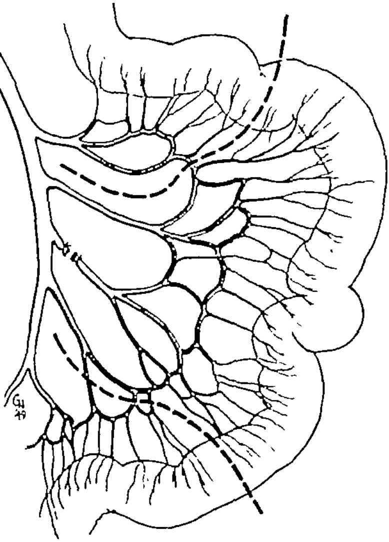

Fig. 10.

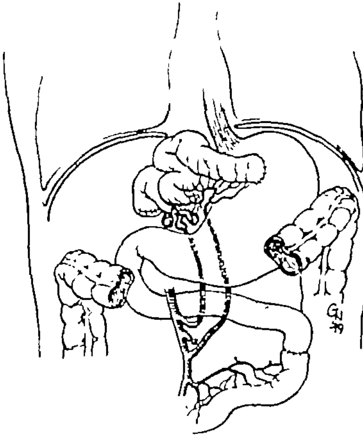

Fig. 11.

Fig. 10.—Plan for first stage of operation showing how bowel will offset upward on blood supply.

Fig. 11.—First stage completed. Isolated segment is actually coiled and covered with veil of *omentum to prevent adhesions. Proximal arm of arterial arch is not divided until* the second stage.

The distal end of the jejunal loop is anastomosed to a fairly large circular ostium in the fundus *of the stomach made by excising a coinlike portion of its wall. The proximal* end of the loop is closed. The loop is then coiled up, covered with a veil of greater omentum to prevent adhesions, and left beneath the diaphragm (Fig. 11).

In the second stage the chest is opened through the seventh interspace and the diaphragm opened anterolaterally for a short distance from the esophageal hiatus. The segment of jejunum is freed with extreme care to avoid tearing away seromuscular layer. The proximal arm of the arterial arch which was tagged previously is divided and the mesentery dissected along the remaining vascular supply to remove peritoneum, lymph nodes, and other tissues restricting length. Care must be taken not to place tension on the vessels which might injure them. The vagus nerves are mobilized from the esophagus and preserved. The esophagus is freed from the mediastinum and transected at the cardia. The opening in the stomach is closed securely to permit early feeding.

An incision is made along the anterior border of the left sternomastoid and both the esophagus and the upper extremity of the jejunal loop are drawn out the neck with as little tension as possible. The jejunal segment may pass on whichever side of the aortic arch that seems best. The loop inside the chest is straightened as well as possible and the excess is replaced in the abdomen where it is fixed as the diaphragm is closed. Penicillin is left

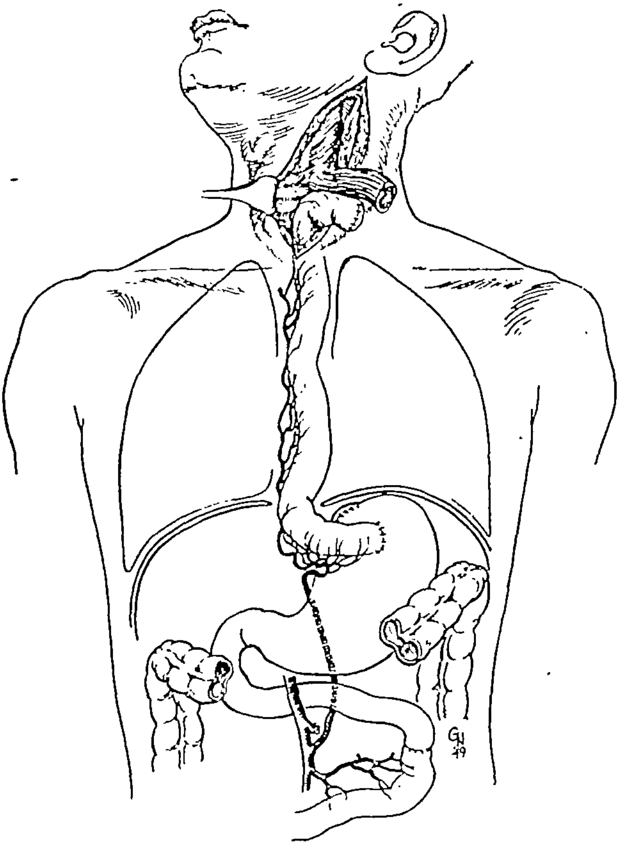

Fig. 12.—Second stage completed. Segment of bowel is much more tortuous than shown.

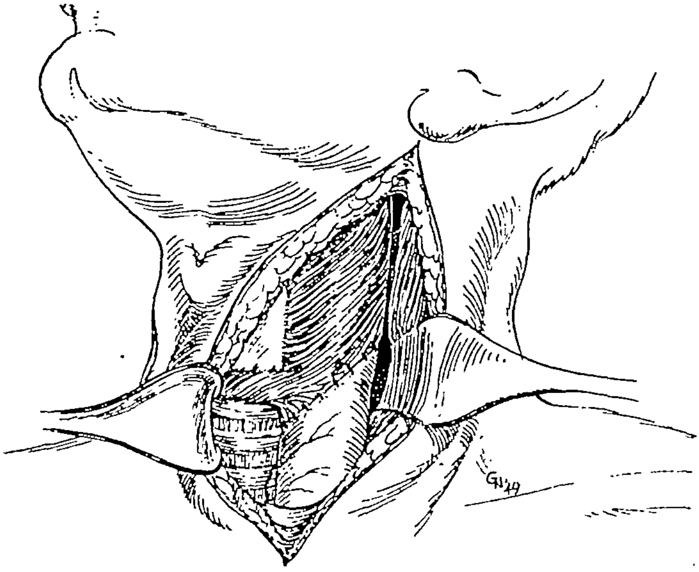

Fig. 13.—Anastomosis of esophagus to jejunal segment is complete.

in the pleural space and two or more intercostal drainage catheters are employed for a few days to insure early and complete re-expansion of the lung. The resulting picture appears in the drawing (Fig. 12).

After the mediastinal space is well sealed, the anastomosis can be made in the neck without fear of possible leakage (Fig. 13). The anastomotic aperture should be made as large as possible by beveling or some such device. A small rubber tissue drain should probably be left in the retroesophageal space postoperatively.

DISCUSSION

Although two cases represent a very limited experience, certain essential features have been observed to contribute most directly to the outcome. (1) In the first stage the jejunal loop must be carefully planned to obtain maximum length of blood supply and minimum length of bowel on its distal end. Although it has not been tried, it would seem feasible even to sacrifice some of the redundant portion of bowel to get a "straight shot" to the stomach. (2) The loop must be transplanted behind both colon and stomach to take full advantage of the length of the artery and to avoid obstruction to stomach or bowel. (3) The loop is closed at its proximal end and anastomosed to stomach at its distal end at the first stage to avoid contamination of the mediastinum during the second stage. (4) A fair-sized coinlike portion of the stomach should be excised for anastomosis to insure adequate centrifugal pull by gastric muscularis for maintaining patency. (5) Extreme gentleness and care are necessary at all times if adhesions are to be avoided. (6) The vagus nerves should be preserved if at all possible. (7) The blood supply should be carefully liberated to its fullest extent by dissecting away peritoneum and lymphatic tissue. (8) Closed drainage of the pleural space postoperatively hastens closure of the mediastinum and prevents infections. (9) The third stage is delayed until the mediastinum is well sealed so there will be no danger should the cervical anastomosis leak. (10) And finally the anastomosis in the neck should be as large as feasible.

The advantages of this method seem to be as follows: (1) The blood supply to the transplanted loop is routed through the shortest most direct path to the neck, thereby creating less difficulty in obtaining adequate circulation. (2) The substitute segment of bowel is shorter and straighter and the ingested bolus "drops" more rapidly to the stomach. This avoids the relative stasis of longer segments. (3) The loop is isoperistaltic and responds well to the stimulus of distention. (4) The stomach retains its normal function regarding both capacity and digestion. (5) Two potential danger points, the anastomosis sites, are outside the chest and thus more accessible if difficulty should arise. (6) The gastrostomy is not disturbed throughout the entire procedure so that there is always a satisfactory means of maintaining nutrition. (7) Last but not least the cosmetic effect is much more satisfactory.

SUMMARY AND CONCLUSIONS

Two case reports have been presented in which complete lye strictures of the cervical esophagus were treated by transthoracic substitution of a loop of jejunum for the esophagus. The three stages of operation for this have been described and the essential features pointed out. The advantages have been enumerated, the disadvantages being taken into account. So far the results have been very encouraging and further trial seems indicated.*

REFERENCES

1. Longmire, W. P., Jr., and Ravitch, M. M.: A New Method for Constructing an Artificial Esophagus, Tr. South. S. A. 57: 346-362, 1946.
2. Rienhoff, W. F., Jr.: Intrathoracic Esophago-jejunostomy for Lesions of the Upper Third of the Esophagus, South. M. J. 39: 928-940, 1946.
3. Yudin, Serge S.: The Surgical Construction of 80 Cases of Artificial Esophagus, Surg., Gynec. & Obst. 78: 561-583, 1944.

DISCUSSION

DR. HERBERT WILLY MEYER, New York.—This interesting paper of Dr. Harrison's is an important contribution to the surgery and reconstruction of the esophagus. The intrathoracic use of a single tube of jejunum to replace the esophagus is a real advance. In 1940 we had to resect the lower thoracic esophagus together with a total gastrectomy for carcinoma. An intrathoracic esophagojejunostomy was employed to re-establish continuity of the intestinal tract. A double-barrel loop of jejunum was brought up into the thorax with an enteroenterostomy lower down within the abdomen. The Roscoe Graham type of anastomosis was employed. There was definite tension at the suture line. We briefly reported this case at the Toronto Meeting of our Association and the case was published in *Surgery* in 1942. I should like to present one lantern slide to show the functioning anastomosis four months after the operation. Dr. Churchill at that time stated that he had performed a similar operation but the patient unfortunately did not survive. We both had found that there was a good deal of tension at the site of the anastomosis if a double-barrel loop of jejunum was employed.

Dr. Harrison's method of using only a single tube of jejunum is a real advance and completely overcomes the objection of tension at the anastomosis. I am certain that this newer and better method will be employed frequently in performing intrathoracic esophagojejunostomy.

DR. RICHARD H. SWEET, Boston.—I hesitate to address you again, especially after such a brilliant procedure which is far better than any of my own experiences in this field, but I would like to tell you that I have also been trying to "out-Rienhoff Rienhoff."

(Slides.) This was another example of the use of the jejunum in the mediastinum, and I am absolutely convinced that that is the proper place for it. I think it is far superior to any external esophagoplasty of any sort whatever, especially using the jejunum. This was a case of lye stricture of the esophagus involving the entire esophagus from the pharynx down.

This is the resected specimen and, because of my preference for one-stage operations, I performed this in one stage with two phases, the abdominothoracic as the first incision, freeing a loop of jejunum, bringing it up and then after a sufficient quantity of jejunum had been obtained, closing the chest incision and making the cervical one. This shows the swallow of barium going down through. The operation is not an easy thing to accomplish, and I am sure Dr. Harrison's method has certain superiorities. This loop was brought up and after transection the proximal end was implanted low down into the distal portion by the Roux type of procedure. The other end was used for the pharyngojejunal anastomosis.

The reason I did not use the stomach in this patient was that she had had the antrum resected because this lye had not only burned the entire esophagus but had also produced a stricture at the pylorus. She had had a partial pylorectomy which made it impossible to mobilize the stomach.

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*At the time of this publication, one year later, both patients eat well and are apparently without complication or difficulty.

DR. WILLIAM F. RIENHOFF, Baltimore.—We have had three successful cases of intrathoracic transplantation of the jejunum following resection of the esophagus and I intend to use this method more frequently in the future, for the simple reason that the jejunum, from the standpoint of length available, prevents difficulties and the size of the eventual tube is better suited to take the place of the esophagus in the mediastinum than pulling up the bulky stomach. I was very much interested in Dr. Harrison's presentation and Dr. Sweet's discussion. Dr. Harrison's leaving the first branch of the vasa recta jejunalis may have a very important role in preventing scarring and curling of the jejunum which is left in the abdomen following mobilization. Dr. Blalock, some years ago, suggested to me that it would perhaps be better to leave the jejunum in the abdomen for a few days after mobilization by cutting the first, second, and third recta jejunalis, dividing the proximal end of the jejunum just distal to the ligament of Treitz. However, it was found that when this was done the jejunum became curled and the vascular comb was shrunk and scarred to the extent that it was very difficult to affect a thoracic bridge or spread out the jejunum sufficiently to bring it into the chest cavity. Attempts to straighten the jejunum would often tear the mesentery and result in interference with circulation to the bowel. These patients were reported in the *Southern Medical Journal* in December, 1946.

A reversed Roux loop, leaving the first vessel departing to the jejunum from the superior mesenteric artery, was performed by me and left in at this time. This left the first artery intact, as suggested by Dr. Harrison. Perhaps some form of transplantation of vessels into the mesentery of the jejunum intrathoracically might be the answer to the problem.

The difficulty in using jejunum heretofore has certainly been one of interference with circulation to the bowel. In a patient reported by Dr. William Longmire, in which he did a subcutaneous transplantation of the jejunum, the internal mammary artery was sutured to one of the jejunal vessels of the vascular comb. This method, however, on account of the very small diameter of the vessel would probably not be practical in the majority of cases and, furthermore, such a vessel could not be used intrathoracically because not enough length could be obtained. If the circulation of the jejunum is maintained, and I think it can be, there would seem to be no question of a doubt as to the desirability of the use of jejunum in preference to the stomach.

DR. CLARENCE CRAFOORD, Stockholm.—I do not know if information is available in this coutry about the work that Yudin in Moscow has done in this field. I have not been able to obtain any accurate information myself, but from Russian surgeons who have visited Stockholm I have heard that he has now done between 200 and 300 operations of this type, anastomosing the jejunum with the esophagus as high up in the neck as the pharynx. In this number are included, I have been told, both cases done in many stages and one-stage procedures, both in front of the sternum and inside the chest. He has also tried the same method that Dr. Harrison has described, but he has found that later on in these stumps, transplanted into the pharynx, there has developed severe irritation even with ulcerations, so he now strongly advises not to anastomose the jejunum with the stomach. He advises letting the food go directly from the mouth into the jejunum, excluding the stomach.

I have performed only one of these operations, and it was astonishing to me to see how long a loop it was possible to obtain with very good circulation by dividing the vessels after the method shown by Dr. Harrison. One can divide four or five branches and get a loop that is about 75 to 100 cm. long, which carries up into the neck without difficulty.

DR. OWEN H. WANGENSTEEN, Minneapolis.—Dr. Harrison's report has been very stimulating. There is an additional maneuver that may be implemented to insure a better arterial blood supply to the jejunal loop swung up into the thorax, a procedure which I have employed several times as an auxiliary to total gastrectomy, with the thought in mind that the capacity of the new jejunal reservoir for food would be increased thereby. The technique consists in denuding the superior mesenteric artery at its root from the aorta from the overlying adventitious tissue; in other words, the superior mesenteric ganglion is removed. This procedure should not only delete the anastomotic arterial channels of the small intestine but should, at the same time, diminish the resistance to distention of the loop, thereby, theoretically at least, making it possible for the patient to eat larger meals without experiencing intestinal colic.

I have had no experience with the procedure described by Dr. Harrison of bringing segments of jejunum up within the thorax. Whether one should anastomose the distal end of that segment to the fundus of the stomach as Dr. Harrison did or re-establish continuity by an end-to-side jejunojejunostomy, as Yudin does and Crafoord prefers, is difficult to decide. An isolated gastric pouch into which neither food nor saliva make their way may invite a duodenal ulcer; on the other hand, may a jejunal ulcer develop at the new jejunogastric anastomotic site if the new esophagus (jejunal segment) is anastomosed to the stomach? In other words, both procedures leave questions unanswered, to be resolved only by time and more experience. In defense of the operation as Harrison did it, there is at least this consideration: a jejunogastric inlet anastomosis probably does not invite a stomal ulcer in the same degree as a gastrojejunostomy outlet, because in the latter instance the stoma is an important outlet for the acid-peptic digestive juice, whereas, in the instance of the jejunogastric inlet anastomosis, there will be only occasionally regurgitation of gastric juice into the proximal jejunal segment. Whereas Dr. Harrison believes it best to leave the vagi nerves in order to avoid gastric retention, vagotomy by reducing gastric secretion may diminish the hazard of a stomach ulcer. If a vagotomy is done, a pylorotomy of the Rammstedt type probably should be added.

There is an additional comment which I should like to make with reference to the nature of so-called idiopathic esophagitis and stricture. The experience of our surgical clinic with the management of these lesions suggests that esophagitis is a manifestation of ulcer disease. My associate, Dr. N. Logan Leven, and I have now observed six patients in whom gastric resection did away with the necessity for continued dilation of an esophageal stricture. The first patient was observed in 1939; an extensive gastric resection was done because of massive hemorrhage for a duodenal ulcer. During the previous five years, the patient's esophagus had been dilated more than 100 times. After a few dilations following gastric resection, the necessity for dilating the esophagus disappeared. During the intervening years, five additional patients with esophageal stricture have been treated similarly with equal success. Some of these patients have had an accompanying ulcer, others have not; one patient had a corkscrew-like stricture of the lower esophagus associated with a congenitally short esophagus. I am now considering the idea of exploring the possibility of whether the dysphagia of cardiospasm as well as that of bona fide lye stricture (of the lower esophagus) also may respond to gastric resection, on the thesis that an active acid-peptic secretion may continue an established vicious circle.

Moreover this much also probably should be said: the esophagus undoubtedly is more susceptible to injury by the acid-peptic digestive juices than is the stomach or the duodenum. And if the esophagus rather than the duodenum were the gastric outlet, I believe that every patient with an active gastric secretory mechanism would have an acid-peptic ulcer in the esophagus. Work now in progress in our experimental laboratory shows definitely the greated vulnerability of the esophagus to injury by the gastric secretions. If a dog's duodenum is obstructed just beyond the pyloric outlet and histamine is given to stimulate gastric secretion, esophagitis with perforation is a common sequel, whereas the stomach in the short postoperative survival period appears to escape unscathed.

DR. HARRISON.—It is indeed gratifying to hear the encouraging comments of these distinguished gentlemen. In answer to Dr. Rienhoff's question, certainly the bowel is inclined to shorten and become adherent, and the mesentery contracts. The purpose in very carefully wrapping this loop of bowel in available omentum is to prevent these adhesions. It seemed to me in these two cases that by carefully dissecting the mesentery and teasing away the restricting tissues the loop should gradually straighten out to the necessary length.

COMPLETING THE MULTIPLE-STAGE OPERATION FOR ATRESIA OF THE ESOPHAGUS

CONRAD R. LAM, M.D.
DETROIT, MICH.

IN 1943, Haight and Towsley[1] reported the first successful surgical repair of congenital atresia of the esophagus by a single mediastinal operation. Since then, there has been general agreement that this plan of attack is far superior to the multiple-stage procedure which resulted in a fair number of surviving children, most of whom, however, carried salivary fistulas and gastrostomies for a long time while they waited for the final construction of the antethoracic esophagus. The improved prognosis in infants treated by primary end-to-end anastomosis is illustrated in Swenson's[2] excellent series. He was able to complete the operation in thirty-two out of thirty-seven cases, and, of these, twenty-seven survived.

In my series of thirteen infants, it was possible to perform a presumably satisfactory anastomosis nine times. Only three of these babies survived; the unsatisfactory results were due to breakdown of the anastomosis four times and anesthetic difficulties twice. Of the four babies who did not have an end-to-end anastomosis, two died in the immediate postoperative period following intramediastinal ligation of the fistula, and futile attempts to connect the segments of the esophagus. The other two children have had the continuity of the alimentary tract established by the construction of an antethoracic esophagus when they were relatively young (at ages 27 months and 18 months). It is with the surgical problem of completing such multiple-stage procedures that this paper is concerned.

As will be seen from the case reports, the sequence of events differed considerably in the two infants. Nevertheless, the final anatomic situations were identical, and the following general plan of management was evolved. If approximation of the two segments is impossible at the time of the mediastinal exploration, the lower segment is detached from the trachea, ligated, and allowed to retract toward the abdomen, and the tracheal opening is closed (Stage 1, Fig. 1). Two days later, if the condition of the infant warrants, the upper segment is exteriorized in the left clavicular region and is opened to permit sham swallowing (Stage 2, Fig. 1). The third stage follows shortly; it consists of mobilization of the cardiac end of the stomach and the lower esophageal segment, through an abdominal approach. The segment is exteriorized through a skin tunnel, the end being brought out as high as possible on the chest wall (Stage 3, Fig. 1). Feedings through this esophagostomy are carried out during the ensuing year by the intermittent insertion of a catheter. Such an esophagostomy is better than a gastrostomy, because the intact cardiac sphincter retains the stomach contents after the removal of the tube and there is no excoriation of the

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skin. Carter[3] suggested such use of the lower segment, but in his one case, an abdominal operation only was done and only that part of the esophagus which could be drawn down through the esophageal hiatus was available. The infant lived only a few weeks. It may be significant that there is no record of an ultimate survival when a blind esophageal pouch has been left attached to the trachea.

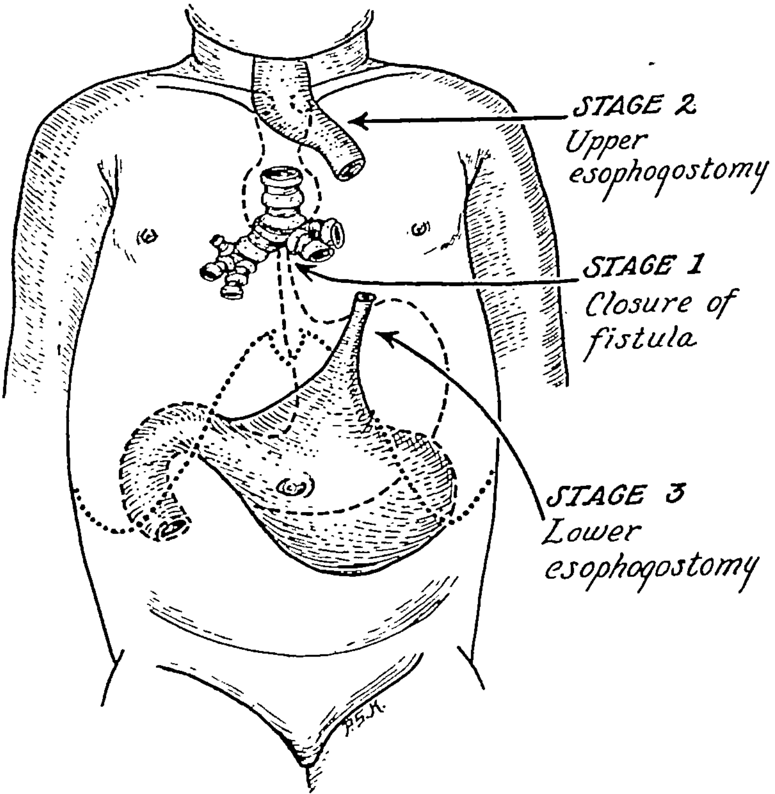

Fig. 1.—Plan of first three operations which may be carried out in the first week if a multiple-stage method of management of congenital atresia of the esophagus is necessary.

During the second year of life, the two esophagostomies are connected by a skin-lined tube. The plan of this phase is illustrated in Fig. 2. Theoretically, the tube could be constructed in three stages, (1) preliminary formation of the tubed pedicles (not shown in Step A, Fig. 2); (2) formation of the tube proper, with covering of its raw external surface with adjacent skin and/or the tubed pedicles (Steps A to D, Fig. 2), and (3) final severance of the pedicles (Step E, Fig. 2). Actually, in the two cases reported below, a considerably larger number of operative procedures were required. Most of the difficulties resulted from attempted short-cuts to avoid the use of tubed pedicles, and from strictures at the esophago-dermic junctions.

CASE 1.—T. R. A preliminary and a progress report on this child have been made in previous communications.[4, 5] He was born in the Henry Ford Hospital on Aug. 1, 1943, and the diagnosis of atresia with tracheo-esophageal fistula was made when he was three days old. Because of the high mortality then associated with the mediastinal operation, I elected to do the multiple-stage procedure, although I have no doubt that the direct

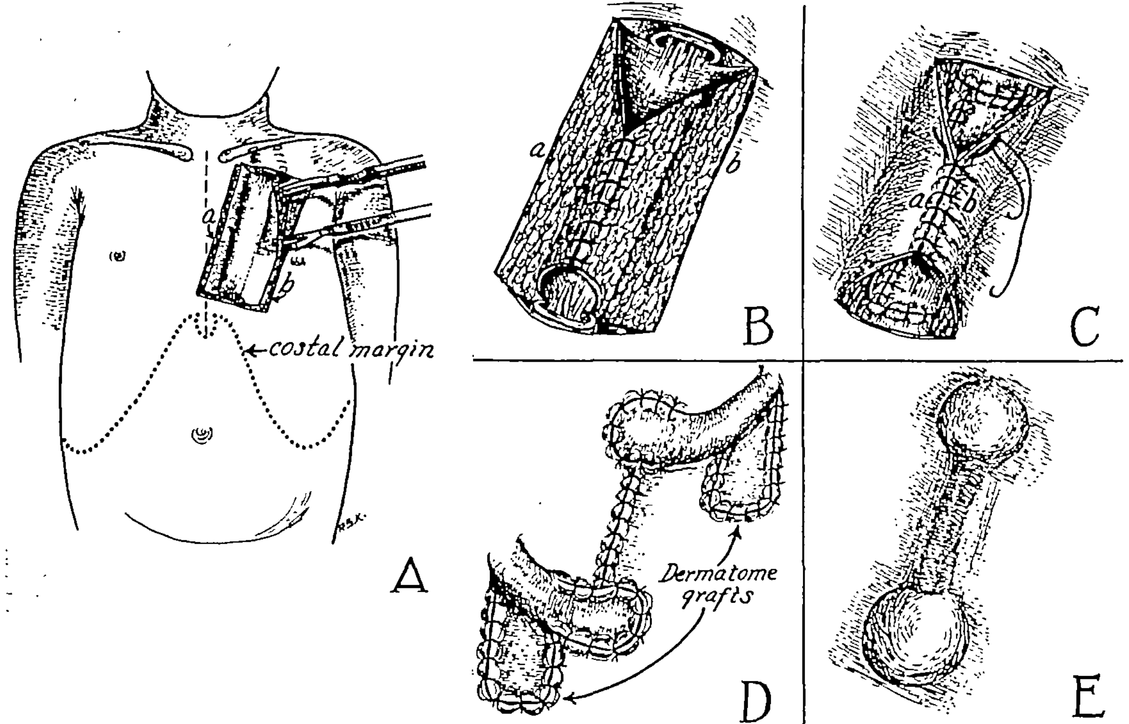

Fig. 2.—Steps in the formation of a dermic tube to connect the two esophagostomies. This stage may be begun when the child is 1 year of age.

operation would have been anatomically feasible. On August 4, under drop-ether anesthesia, the stomach was transected as near the cardiac orifice as possible and mushroom catheters were placed in the two parts of the stomach. The one on the pyloric side was used for feeding and the one on the cardiac side was used to drain the remaining lower segment of esophagus. Such a procedure was once used by Gamble,[6] whose patient died on the twelfth day from perforation of the stomach. It was similar in principle to a plan followed by Leven[7] on a child who is now the oldest patient to survive any kind of attack on the anomaly.

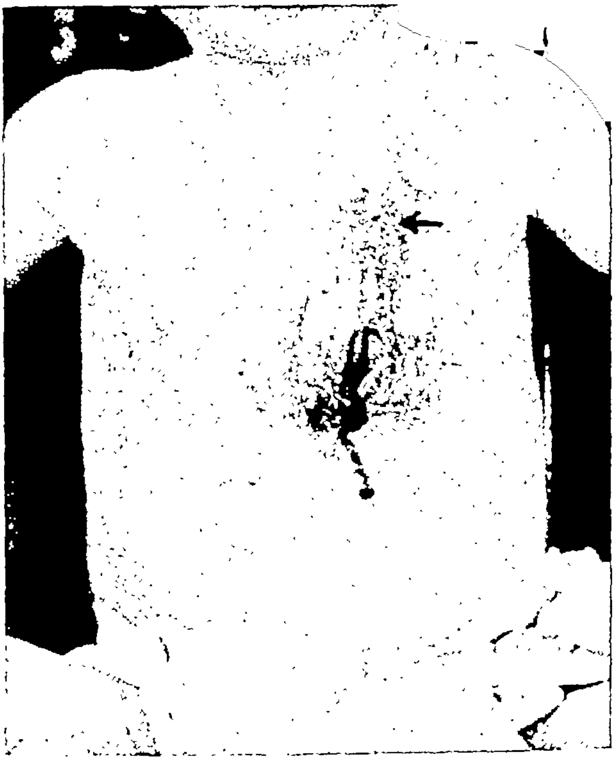

Fig. 3 (Case 1).—Photograph taken after the first attempt to form the skin tube. Note the upper small defect (arrow) and the larger lower defect which has been temporarily bridged with a piece of rubber tubing.

On August 18, the upper segment of esophagus was exposed through an incision along the anterior border of the left sternomastoid muscle, and its length was such that the end could be exteriorized through an opening in the skin below the clavicle. (Stage 2, Fig. 1.) At the age of one month, he was discharged to home care. The plan was to allow him to attain the age of one year before anything further was done. However, on Jan. 21, 1944, he was admitted as an emergency case because he had coughed up some food which had been placed in the distal gastrostomy. It was obvious that a fistula had formed between the two portions of the stomach, and it was urgent to disconnect the lower segment from its fistulous connection with the trachea. On January 24, I opened the left pleural cavity through the seventh interspace. The esophagus, which was the size of the little finger, was picked up and traced to where it joined the trachea at its bifurcation. It was doubly ligated at this point and cut. The diaphragm was opened and the cardia was mobilized by cutting the short gastric and left gastric vessels and the end of the esophagus was brought out through a stab wound in the left lateral abdominal wall. It could not be brought to its final location on the anterior chest wall because the two gastrostomies were in the way. On February 11, the continuity of the stomach was re-established and the two gastrostomies closed. Feeding was now easily accomplished by the intermittent insertion of a catheter into the lateral esophagostomy. On February 19, he was discharged again for home care.

On Aug. 10, 1944, when he was a little over 1 year old, he was admitted for the construction of the antethoracic esophagus. As a first step, the lower segment of esophagus was moved from its position on the lateral abdominal wall to a point above and to the left of the xiphoid. Thus, the situation in Stage 3, Fig. 1 was not accomplished in this patient until he was a year old. On September 8, an attempt was made to construct a skin tube connecting the two esophagostomies according to steps A, B, and C in Fig. 2. Due in part to malnutrition, the skin of the chest wall was so loose that I yielded to the temptation to close the triangular defects seen at each end of the tube in Step C by continuing the linear suturing until the entire raw surface of the tube was covered without the use of free or pedicle grafts. The result looked very good immediately after the operation, but on the fourth day, there was opening up of the tube at the lower end for a distance of several centimeters. The main factor in this appeared to be adherence of the two suture lines, with the result that pull on the external skin also tended to pull the suture line of the dermic tube apart. For this reason, it has been indicated on Step C, Fig. 2, that if such a closure is contemplated, the suture line in the dermic tube should be eccentrically placed so that it will not lie immediately under the outside suture line.

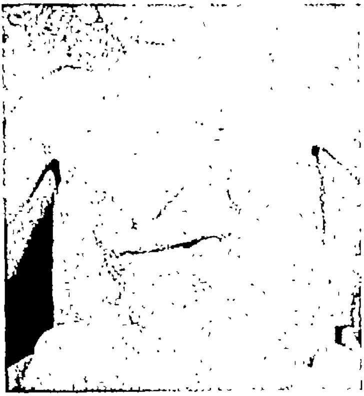

Fig. 4 (Case 1).—A tubed pedicle is being utilized to cover the lower defect.

The appearance of the abdominal wall after this stage is shown in Fig. 3. In addition to the large lower defect, there was a small leak higher up. Further attempts to complete the tube were postponed until the tissues were softer. Then on February 5, the lower part of the tube was closed again, and the raw surface was covered with a dermatome graft. This stage was also a failure, and it became obvious that nothing short of a substantial pedicle graft would give permanent closure. Consequently, on February 19, a pedicle was raised on the right side of the abdomen, and on March 5, this was used to cover the lower part of the dermic tube which was formed for the third time (Fig. 4). On April 30, the pedicle was cut loose from the right side of the abdomen and the excess tube was attached at a point higher on the chest in order that the part not needed for the lower defect could be used for a patch over the upper defect. This procedure was done on May 18. The upper opening did not remain closed, and it was utilized as an opening through which to dilate both the upper and lower esophagodermic junctions with olive-tipped dilators (up to size 8 common duct dilators). The stricture at the lower junction was so tight that on September 7, its posterior aspect was exposed and it was corrected by a plastic procedure, a longitudinal incision being closed transversely. Dilatations were continued by passing the dilators through the upper opening until it appeared that a satisfactory lumen would be maintained. On Nov. 15, 1945, the edges of the upper opening were freshened and it was closed by suture. This was the last of twenty trips to the operating room. There has been no leakage since, and the child has consumed a full diet at the family table without interruption. Fluids and soft food are ingested readily. When eating solid food rapidly, he sometimes gives the external esophagus a quick push with his wrist. His development has been normal in every way.

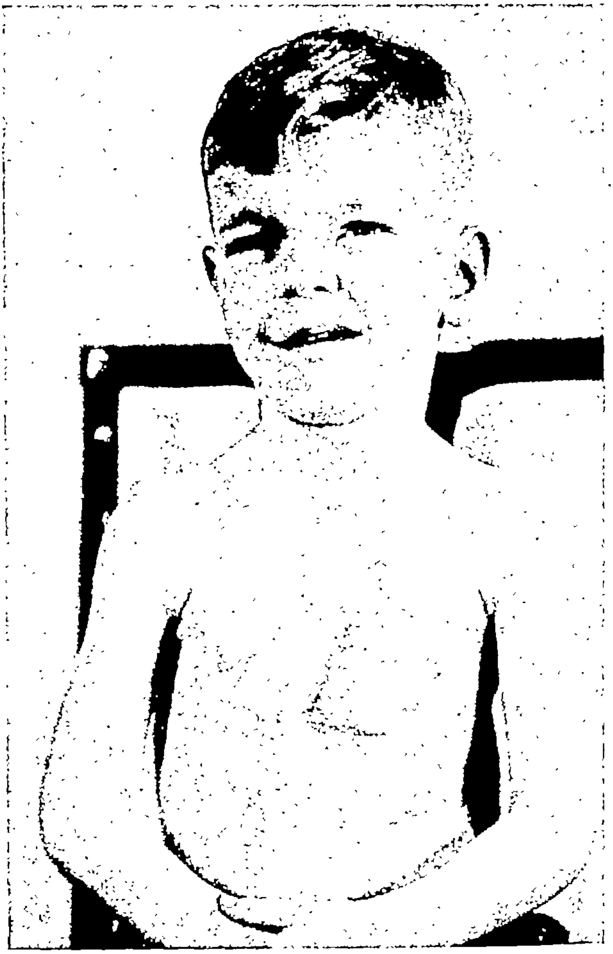

Fig. 5 (Case 1).—Patient at the age of 5 years, showing completed antethoracic esophagus.

CASE 2.—E. L., a boy (Case 7 in a previous communication[5]), was born on Dec. 8, 1945. On December 11, the diagnosis of atresia and tracheoesophageal fistula was made, and I immediately explored the mediastinum. The fistula was closed, and an attempt was made to form an end-to-end anastomosis, but the gap between the segments was too great. The lower segment was allowed to retract toward the abdomen, and the opening which had been made in the upper blind pouch was closed temporarily. (Stage 1, Fig. 1.) Three days later, the upper segment was exteriorized in the clavicular region (Stage 2, Fig. 1). Two days later, a transverse incision was made beneath the left costal margin and after section of the short gastric vessels, the left gastric artery and the vagus nerves, the lower segment of esophagus was drawn out of the hiatus and brought through a subcutaneous tunnel to a point to the left of the midline of the chest. (Stage 3, Fig. 1.) It will be noted that these three operative procedures over a period of a week accomplished the same anatomic result that five operations over a period of one year did in the first case (Fig. 6).

On March 18, a hernia of the left subcostal incision was repaired, and at the same time, a small pedicle was raised on the left side of the abdomen. This was only about 4 cm. in length, but it became necrotic in the middle. On August 14, an attempt was made to construct the dermic tube. As in Case 1, the skin of the adjacent chest wall was so loose that it could be brought over the tube without obvious tension, and no pedicle grafts were utilized. However, as a safety factor, relaxing incisions were made at each end of the tube. Again, the tube opened up, this time at both ends, leaving a tunnel between. This tube was dilated by passing olive-tipped dilators in both directions. On Jan. 6, 1946, a tubed pedicle from the left axillary region was used to cover the upper defect. Before healing was complete, a stricture developed in the end of the upper esophageal segment, and a small plastic procedure was carried out. The closure of the lower opening was delayed to permit occasional dilatations of the upper part of the tube, and on May 16, 1947, the lower defect was covered with a pedicle from the right side of the abdomen. The final operative procedure was on June 9. There had been a total of eleven trips to the operating room. Twice since then a small area of infection has developed in the suture at the medial and lower part of the tube. This has been followed by some leakage of fluid, but each time the opening closed spontaneously in two weeks. The tube has been water-tight for four months, and the child is eating normally (Fig. 7).

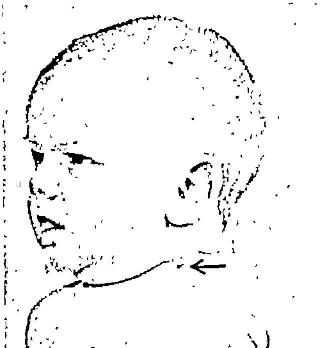

Fig. 6 (Case 2).—Patient at the age of 2 months. Upper arrow points to cervical esophagostomy which permits sham swallowing. The lower arrow points to the lower esophagostomy through which a catheter is inserted at feeding time. Note the absence of skin irritation from digestive juices, usually present with a gastrostomy.

There are other methods of constructing an antethoracic esophagus, many of which are reviewed by Yudin.[8] Ladd[9] constructed a long dermic tube to connect the cervical esophagostomy with a gastrostomy in the epigastric region in several patients. This was successful in at least one case, a girl who is now nearing her ninth birthday. Later, Ladd and Swenson[10] indicated that they had become discouraged with a method which involved the anastomosis of a skin tube directly to the stomach and recommended the use of a jejunal transplant to connect with a short dermic tube. With this plan, food completely bypasses the stomach, at least a theoretic objection. The group at the Children's Hospital in Boston have not remained enthusiastic about jejunal grafts, because in a recent article, Gross[11] had the following to say with regard to Yudin's method in adults: "In our clinic, attempts at similar jejunal transplantation in children (for the treatment of esophageal atresia) have been troublesome or have failed because of the shortness of the loop which can be brought up onto the chest or because of insufficient blood supply (and sloughing) of the limb."

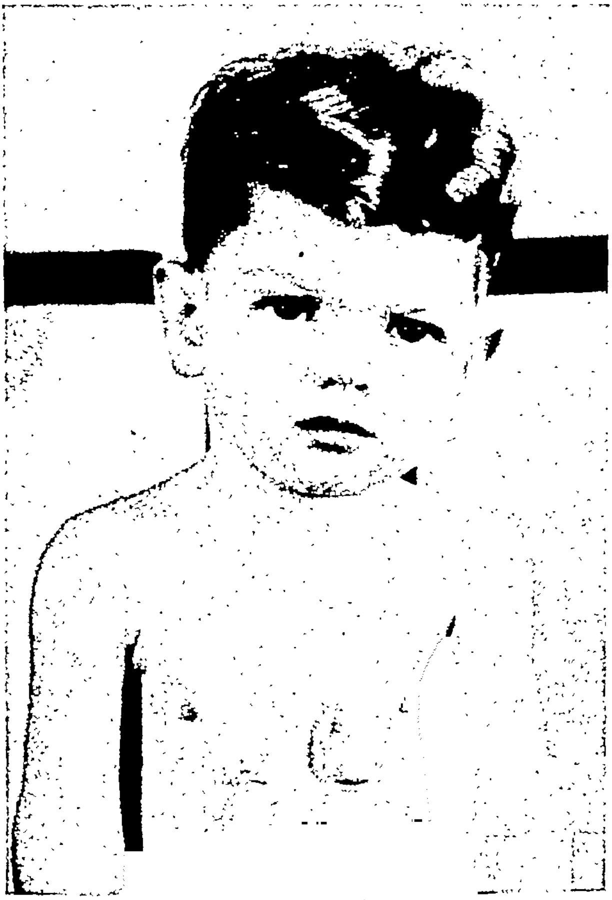

Fig. 7 (Case 2).—Patient at the age of 2½ years, with completed antethoracic esophagus.

Longmire and Ravitch[12] have devised a method of mobilizing a considerable length of jejunum by transplanting it into a skin tube raised in the left abdominal region, and later stepping this up into position on the chest. They were successful in one adult with a chemical stricture. The same method was used to connect the two esophagostomies of an infant with atresia who had had the preliminary stages thirteen months previously. This patient died at the age of 34 months, at which time there was still a fistula at the site of the esophagojejunal junction.

Rienhoff[13] recently reported two cases of atresia in which as a primary operation he had divided the esophagus at the diaphragm and mobilized the stomach so well that the cardiac end could be brought up through a skin tunnel and anastomosed directly to the upper esophagostomy without the intervention of a dermic tube. A patient operated on in 1941 lived one year and died of "staph. infection and diarrhea." His second patient also lived one year and died of diarrhea and a respiratory infection.

Still more recently, Sweet[14] described a new method by which he had completed the multiple-stage operation in a 21-month-old boy by bringing the mobilized stomach up through the chest and out to the left side of the neck through an opening made by resecting a portion of the left clavicle and first rib. He felt that the result was generally satisfactory, but the early reports indicated an unsatisfactory weight gain.

SUMMARY

In the management of two infants with atresia of the esophagus in whom the superior operation of direct anastomosis was not carried out, it was found to be advantageous to exteriorize the lower segment for feeding during the first year. Plastic procedures to connect this esophagostomy with the upper esophagostomy with a dermic tube were completed in one child when he was 27 months old and in the other when he was 18 months old. Disappointments encountered during the construction of the tubes probably could have been avoided by the use of pedicle grafts to cover the denuded areas. The function of the antethoracic esophagus in these cases appears to be as satisfactory as that obtained when more complicated procedures, such as jejunal transplantation, are utilized.

REFERENCES

1. Haight, Cameron, and Towsley, H. A.: Congenital Atresia of the Esophagus With Tracheo-esophageal Fistula, Surg., Gynec. & Obst. 76: 672, 1943.
2. Swenson, Orvar: Diagnosis and Treatment of Atresia of the Esophagus and Tracheo-esophageal Fistula, Pediatrics 1: 195, 1948.
3. Carter, B. N.: An Operation for the Cure of Congenital Atresia of the Esophagus, Surg., Gynec. & Obst. 73: 485, 1941.
4. Lam, C. R.: Surgical Treatment of Congenital Atresia of the Esophagus, J. Pediat. 27: 456, 1945.
5. Lam, C. R.: Further Experiences in the Surgical Treatment of Congenital Atresia of the Esophagus With Tracheo-esophageal Fistula, Surgery 20: 174, 1946.
6. Gamble, H. A.: Tracheo-esophageal Fistula: Description of a New Operative Procedure and a Case Report, Ann. Surg. 107: 701, 1938.
7. Leven, N. L.: Congenital Atresia of the Esophagus With Tracheo-esophageal Fistula: Report of Successful Extrapleural Ligation of a Fistulous Communication and Cervical Esophagostomy, J. Thoracic Surg. 10: 648, 1941.
8. Yudin, S. S.: The Surgical Construction of 80 Cases of Artificial Esophagus, Surg., Gynec. & Obst. 78: 561, 1944.
9. Ladd, W. E.: The Surgical Treatment of Esophageal Atresia and Tracheo-esophageal Fistulas, New England J. Med. 230: 625, 1944.
10. Ladd, W. E., and Swenson, Orvar: Esophageal Atresia and Tracheo-Esophageal Fistula, Ann. Surg. 125: 23, 1947.
11. Gross, R. E.: Treatment of Short Stricture of the Esophagus by Partial Esophagectomy and End-to-End Esophageal Reconstruction, Surgery 23: 735, 1948.
12. Longmire, W. P., and Ravitch, M. M.: A New Method of Constructing an Artificial Esophagus, Ann. Surg. 123: 819, 1946.
13. Rienhoff, W. F.: Antethoracal Transplantation of the Stomach in the Treatment of Congenital Atresia of the Thoracic Esophagus, Bull. Johns Hopkins Hosp. 82: 496, 1948.
14. Sweet, R. H.: A New Method of Restoring the Continuity of the Alimentary Canal in Cases of Congenital Atresia of the Esophagus With Tracheo-esophageal Fistula Not Treated by Primary Anastomosis, Ann. Surg. 127: 737, 1948.

DISCUSSION

DR. RICHARD H. SWEET, Boston.—If you will bear with me once again I will promise not to discuss another paper. I am much interested in Dr. Lam's experiences, which are about the same as we have had. The construction of an external esophagus from a skin tube is a tedious procedure. As he did, I have likewise tried pulling the stomach up for use as the lower end of the external esophagus. I would like to make a suggestion as to how this may be handled differently.

(Slides) This illustrates how I have handled these cases. A thoracic incision is made and the diaphragm is opened. The gastrostomy is closed, and the stomach pulled into the chest. After closing the thoracic incision, the proximal end or fundus of the stomach was brought up into the neck through a cervical incision after resection of a portion of the clavicle and a portion of the first rib as shown here.

This has been done in two infants, one about a year ago and one five or six months ago. They are getting along normally and beginning to develop. This is a one-stage operation and obviates the necessity for mechanical assistance. These children eat normally and are not aware of the fact that they have a stomach that has been pulled up into the neck.

DR. LLOYD H. MOUSEL, Washington, D. C.—If I may be allowed to digress for a moment, I would like to express my pleasure in learning at this meeting that the majority of major thoracic surgical clinics have abandoned the use of cyclopropane. During the past several years during which a number of deaths on the operating table have been reported, this agent was being used. Most of these deaths have been attributed to vasovagal or vagovagal reflex activity. It is my personal belief that deaths on the operating table due to cardiac standstill can be greatly reduced, if not entirely eliminated, if cyclopropane is not used.

In managing patients who are undergoing resection of the esophagus, positive pressure is maintained in the closed anesthesia system at all times, in order to prevent bilateral pneumothorax from developing should the opposite pleura be opened. Large openings into the opposite pleura are usually recognized by the surgeon and the lung can be kept inflated until the pleura has been closed. However, if a small opening is made into the opposite pleura, it may go unrecognized if positive pressure is not being maintained, and a complete pneumothorax may develop. Our patients are watched very closely on the operating table and great care is taken to prevent such a development.

Following each major thoracic surgical procedure, our patients are x-rayed on the operating table. If there is evidence of air in the pleural cavity, it is removed before the patient is returned to his room.

In our particular area, two cases have been reported in which the patient died on the operating table, due to accidental entrance into the opposite pleura. These patients were both undergoing lumbodorsal sympathectomy. In each instance the patient developed an obstructive type of breathing, and it was felt by the surgeon and the anesthetist alike that some obstruction to the airway had developed. Attempts were made to aspirate material from the tracheobronchial tree without results. Both patients deteriorated very rapidly and died before they were removed from the operating table. In each instance at post-mortem, it was found that the patient had died of bilateral pneumothorax. These are accidents that do not occur often and can be prevented by the use of constant positive pressure during the time the mediastinum is open.

DECORTICATION IN PULMONARY TUBERCULOSIS INCLUDING STUDIES OF RESPIRATORY PHYSIOLOGY

Joseph Gordon, M.D., Ray Brook, N. Y., and Edward
S. Welles, M.D., Saranac Lake, N. Y.

THE historical identification of the decortication operation has been previously made by the late Dr. Fraser Gurd[1] and will, therefore, not be further considered. The present revival of interest must be dated from the reports given at the Detroit Meeting of this Association in May, 1946, on chronic traumatic hemothorax and empyema.[2-4] The purpose of this presentation is to relate experiences gained thus far in exploring the applicability of decortication to the inexpansible tuberculous lung. The eight cases to be reported upon is a small number for a series, but serve as a basis for suggesting a method of study from which helpful conclusions might be drawn. The operative technique has been established and need not be reported here.

The problem of hemothorax and pyothorax with or without air present is not entirely comparable with that of the inexpansible tuberculous lung and empyema. Common to both is the objective of obliterating the pleural space by re-expansion of the lung. The fundamental pathology and method of treating the underlying pulmonary disease are not the same. The treatment of the pleural complication in the former generally represents an end point. In the latter, the pleural problem is always secondary to the parenchymal disease which is the chief consideration.

For the prime purpose of obliterating the pleural space, thoracoplasty alone has proved satisfactory in many cases. Upon occasion, in the presence of bronchopleural or pleurocutaneous fistulas, the addition of a Schede or myoplastic operation has been required. While thoracoplasty accomplishes a twofold purpose, permanent collapse of the diseased lung and obliteration of the pleural space, it does so at the sacrifice of good functioning lung in certain cases. For this reason and because of the desire of avoiding more mutilating surgery, the decortication operation suggests itself. The comparison of results must be made between the two procedures. In attempting to bring about re-expansion of a lung in which tuberculosis has been successfully treated, one must be mindful of possible harmful effects. The question of risk is naturally posed. This must be weighed against the hazard of long-sustained pneumothorax. Once it has served its purpose, it is desirable to abandon the pneumothorax, as expected reversibility is one reason for its application.

That decortication is possible in cases of pulmonary tuberculosis has been demonstrated in several reports: Gurd,[1] Mulvihill,[5] Curreri and Gale,[6] and Lam.[7] It was recognized at the outset that because of variable extents of parenchymal disease for which the lungs were collapsed, re-expansion and improved function

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Read at the Twenty-eighth Annual Meeting of the American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

might not necessarily follow. In anticipation of such problems a cooperative study was outlined with Dr. George Wright, of the Trudeau Foundation Physiology Laboratory.

The starting point for considering treatment of a disease or complication is a knowledge of its pathology. The detailed pathology of tuberculosis need not be considered here. The effect of long-sustained collapse on the underlying lung is of importance and serves to answer the question, "Can the lung be re-expanded?" The morphology of collapsed uninvolved pulmonary tissue as given by Vorwald[8] is as follows: "There is collapse of the alveolar spaces, the walls of which are approximated, but the architecture of the lung is not obliterated; there is histocytic proliferation of the alveolar walls and in the perivascular and peribronchial spaces with a slight increase in connective tissue; the blood vessels are more or less tortuous and the capillary spaces dilated; the lymphatics are little altered but may be dilated; the degree of connective tissue proliferation is not irreversible." The experimental work of Bruns,[9] and the studies reported by Gardner[10] and Pinner[11] are the basis for the conclusions that "fibrosis in a collapsed lung is the result of inflammatory processes and not of the collapse per se." It is upon this basis that re-expansion of the uninvolved portions of the lung is expected. The anticipated degree of re-expansion, judged by the prepneumothorax extent of disease does not necessarily follow. Gardner stated that "extension of disease within the compressed lung may proceed by way of the air passages and, to a more limited degree, through the lymphatic channels. Hematogenous metastasis is probably rare." These data serve as a working base line for approaching the present problem.

The cases selected for treatment were those in which there was evidence of failure of obliteration of the pleural space by the lung. All measures to have the lung re-expand and obliterate the pleural space had failed. There was no question that perhaps in time this might yet occur. Cases with advanced stenosis of a major bronchus were excluded. In these it was felt that re-expansion was probably impossible and undesirable for fear of increasing the broncho-parenchymal bed distal to stenosis and risking suppuration. In five cases (Cases 1, 2, 3, 4, and 5) the duration of the pneumothorax was over years and the paren chymal disease was considered arrested, the sputa having been negative. Seven of the eight patients had fluid present which was positive for tubercle bacilli, two showing frank pus. Two patients (Cases 6 and 7) had active pulmonary disease, with cavities and positive sputa. In these thoracoplasty was done first to collapse the disease-containing parenchyma before decortication was undertaken. In Case 8, there was a history of pleurisy with effusion twenty-seven years before with recurring symptoms in 1942 and 1947. There was no clear-cut history of pulmonary tuberculosis until 1947, when a small antrum was noted on the contralateral side (left), the sputum and fluid were both positive, and intermittently a bronchial fistula could be demonstrated.

The history and all available films of each case were carefully reviewed. A careful fluoroscopic survey as well as a study of inspiration-expiration films indicated the present mobility of the lung. The factors of compensation, intrapleural pressures, frequency of refills and the speed of re-formation of fluid were noted. All were bronchoscoped before operation and special respiratory studies were also made, both before and after decortication. In two cases preliminary bronchograms as well as two other postdecortication bronchograms were made.

From these preliminary studies a decision was made as to whether a thoracoplasty would be done before undertaking the decortication. In two of the arrested cases (Cases 2 and 3), it was elected to do two stages of thoracoplasty because of the extensiveness of the tuberculosis before pneumothorax. It was reasoned that insufficient good lung remained to anticipate enough re-expansion to fill the large pleural space. In Case 2 there was some arterial oxygen desaturation observed after exercise on a motor-driven treadmill. Decortication resulted in decreasing the pleural space and some increase in lung volume but no functional improvement. It was, therefore, felt that additional thoracoplasty should be done to aid in obliteration. This has recently been done and there is evidence that a satisfactory result will ensue. In Case 3 decortication obliterated the small residual space. It is expected that no functional change has resulted. In Case 1 the patient had been treated with an emergency thoracotomy drainage because of fulminating uncontrollable mixed-infection empyema and bronchopleural fistula. Subsequent multiple-staged thoracoplasties were done to obliterate the large empyema space further to control the toxemia. A residual pleural space and cutaneous fistula at the site of the thoracotomy wound remained. Decortication was carried out in preference to a Schede operation; the lower lobe was mobilized and a good result obtained. The patient was discharged as well and has been working for a year. In Cases 4, 5, and 8 primary decortication was performed. In Case 4 ultimate complete obliteration of the pleural space was accompanied by further desaturation of the arterial blood; the detailed report of this case will be given by Dr. Wright.[12] Incomplete obliteration of the pleural space with fluid forming in the presence of high negative intrapleural pressures resulted in Case 5, with no significant change in pulmonary function. The primary pleurisy with effusion case of twenty-seven years' duration (Case 8) has almost complete obliteration, but it is too recent postoperatively to evaluate.

In the two cases in which thoracoplasty was done for active pulmonary disease, decortication resulted in obliteration of the remaining pleural space, thus obviating the need for further thoracoplasty. These two are of additional interest regarding findings at the time of decortication. In Case 6, a completely collapsed lower lobe was found covered with peel. A second review of the films indicated that this might have been anticipated. With removal of some peel, tubercles were seen and it was elected not to complete the operation except over the uninvolved portion of the upper lobe. After decortication the lower lobe of Patient P. R. in Case 7 appeared slate-blue in color and, though the lobe was distended with positive pressure, the color did not change to the usual pink. The significance of this finding is not clear.

In all except the case with the twenty-seven-year history, the removal of the visceral pleural peel was relatively easy to accomplish with minimum trauma to the lung. In this case much sharp dissection was required and a strawberry-like appearance was seen on the pleural side of the cortical layer. In all cases there were areas where the peel was most adherent which were considered healed foci. After a brief trial at removal these were circumvented and allowed to remain in patches. Studies before operation showed in all cases some reduction in respiratory function proportional to the extent of the pulmonary problem. Those studied postoperatively thus far have not shown any significant gain in function as contrasted with one nontuberculous traumatic hemothorax case to be discussed elsewhere.[12]

There were no spreads of disease, but it must be stated that streptomycin was used for short periods of time, both pre- and postoperatively. The significance of this therapeutic adjunct is not known. All cases were on continuous suction for from forty-eight hours to five days. There were no recurring empyemas and all wounds healed by primary union.

In addition to the above-noted results there are some points which require further consideration. What of the re-expanded lung? Will it be normal healthy lung, or one showing compensatory dilatation or, one step further, true pathologic emphysema? The lung may be ventilated with poor circulation, or have good circulation and be poorly ventilated. There may be satisfactory readjustment or the development of a shunt between unaerated and aerated blood. The volume of lung for re-expansion is unknown because the amount of interstitial fibrosis cannot be determined. The amount of disease seen in roentgenograms is by no means an index of all that is present. With healing and scar formation of the diseased areas there are local compensatory changes in the surrounding lung tissue. In addition, there is the probability that, under partial pneumothorax at least, compensatory changes in the lung have already taken place. Hence, some limit of distensibility may have been reached and may account for the failure of further expansion. It is known that in certain cases where no previous pleural complications are suspected transudate fluid forms to take up the space the lung cannot occupy. In these, perhaps the limiting membrane may be a secondary formation rather than the cause of limited expansibility. In several cases bronchography has been done and there is some suggestion that it may be helpful in estimating the above-mentioned changes. How long after decortication does it take the lung to return to normal? For the present the answer cannot be given. These are the observed facts: (1) Immediately upon removal of the peel, the lung becomes distensible by positive pressure on the anesthetic bag with an intratracheal tube present; (2) increase in lung volume is noted within several days as seen on postoperative roentgenograms; (3) the diaphragm is seen to move in a normal direction. Recheck bronchospirometry is planned and in one nontuberculous case progressive improvement in function was recorded. That some time must elapse before the uninvolved portions of the lung become restored might be expected in considering the previously described histopathology. A certain lapse of time was required to produce these changes and should be necessary before function is restored. This is certainly true of other immobilized parts of the body. Regarding the peel that is left behind, since the etiology of the fluid is generally tuberculous and since these effusions and empyemas are clinically known to regress and recur, the question arises as to possible recurrence in the decorticated case. Insufficient time has elapsed in this group of cases to permit making a statement. It might be of some significance, however, that histologic examination of these peels show nonspecific scar in the older cases and tubercle formation in the more recent ones. Further, the fluid was examined and, in cases previously positive on smear and culture, has been negative by culture postoperatively. The parietal peel was more difficult and was only partially removed in some cases. Experience indicated that a plane of cleavage was easier to develop at the endothoracic fascia, where bleeding was most profuse, than between pleura and cortical layer. Whether or not it is essential to remove the parietal peel is not known. There is some suggestion that this may not be entirely necessary. For example, it is well known that, in certain chronic empyema cases, apparent resolution takes place so that no evidence of the previously designated "thickened pleura" is roentgenographically demonstrable (Case 9). In addition, the previously observed compensatory factors of flattening and immobility of the chest wall are replaced by normal contour and movement in the presence of a good functioning

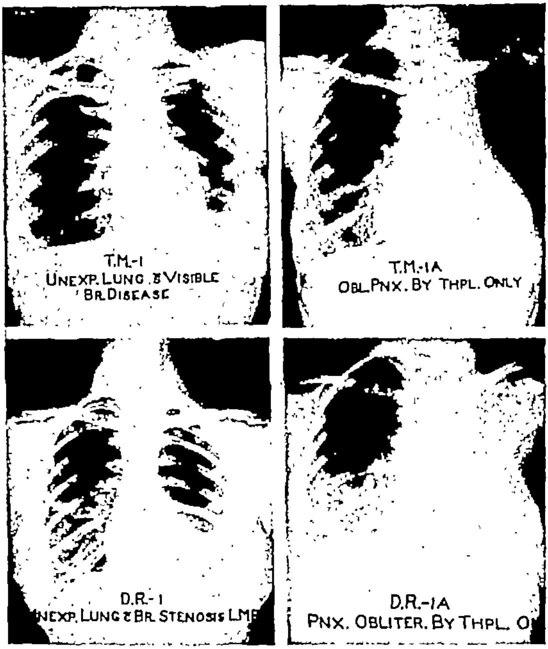

Fig. 1.—T. M. *1*, showing unexpandable left lung, pneumothorax space with fluid present. No evidence of bronchial disease by bronchoscopy. T. M. *1A*, showing obliteration of entire pneumothorax space by thoracoplasty only. D. R. *1*, showing almost total collapse of left lung, large pneumothorax space, bronchial stenosis of left main bronchus seen by bronchoscopy. D. R. *1A*, showing satisfactory obliteration of left pleural space by thoracoplasty alone.

lung. Further, some of the decorticated-hemothorax cases did not have the parietal peel removed and are reported as restored to normal function. Of particular consideration in these tuberculous cases is the fact that the volume of lung for re-expansion is an unknown quantity. A completely intact hemithorax may not be required because of limited distensibility of the lung and the pleura may be again thickened as a compensatory factor following re-formation of fluid.

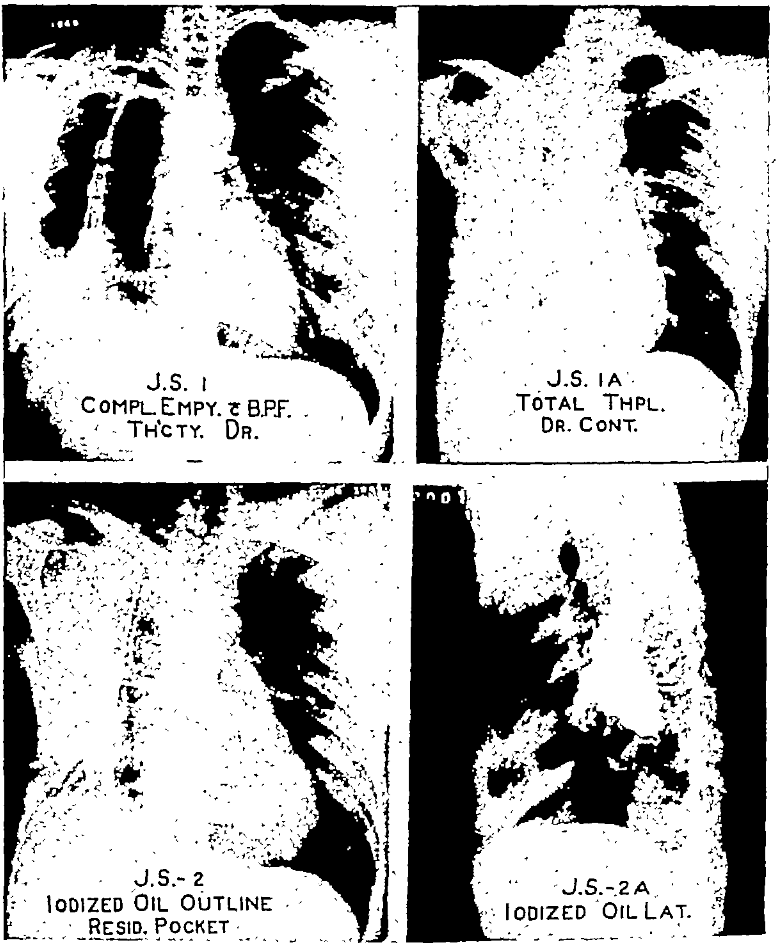

Fig. 2 (Case 1).—J. S. *1*, film showing partially collapsed lung with markedly thickened peel on both pleurae, thoracotomy tube drainage because of bronchopleural fistula. J. S. *1A*, film showing total thoracoplasty collapse, tube drainage still present. J. S. *2*, film showing outline of residual empyema pocket in the posteroanterior projection. J. S. *2A*, same as above in the lateral projection.

A further point for longer term observation is the possibility of development of a reactivation of disease at a later date in the re-expanded lung. Is there a possibility that this distended or emphysematous lung is made more vulnerable to the development of active disease? There is some suggestion, but not proof, in some of the obliterating so-called "re-expanded pneumothorax" cases. With mediastinal shift to the obliterating side and increased size of the contralateral lung new disease or reactivation of stable foci have been noted to develop. This point alone is of little moment, but in reinducing collapse of the nonexpansible lung or performing a thoracoplasty to aid in pleural space obliteration, rather prompt clearing of these foci in the opposite lung has been observed. The problem needs study and would require the scrutiny of statistical analysis for acceptance.

CASE REPORTS

CASE 1.—J. S., a white man, 26 years of age, with onset of disease in 1939, had a pneumothorax, right, started in July, 1940, later complicated by a spontaneous pneumothorax with fluid formation, June, 1942. He was treated by many chest aspirations and continuation of therapeutic pneumothorax. In March, 1945, the patient developed a fulminating mixed- infection empyema and bronchopleural fistula necessitating intercostal thoracotomy drainage in April, 1945. Three stages of thoracoplasty with resection of segments of ten ribs was completed on Oct. 18, 1945. General health improved but there remained a residual pleural space and a pleurocutaneous fistula at site of thoracotomy. Decortication was done in preference to Schede's operation on March 6, 1947. The regenerated chest wall was stiff and retraction difficult, but peel was easily removed, fissures were open, and the lung was inflated satisfactorily. Fluid from empyema was mixed, Staphylococci, Streptococci, and Pneumococci, as well as positive culture for tubercle bacilli. Sputum was negative before thoracoplasty and thereafter. All fluid was negative postdecortication. Patient was discharged well on May 20, 1947, and has remained well and working one year to date.

Comment.—The common complications of long-standing pneumothorax occurred: fluid formation, inexpansible lung, mixed empyema with bronchopleural fistula. Emergency treatment was required, thoracotomy, thoracoplasty, but a residual space and a sinus tract remained. The usual treatment of such cases has been by Schede's operation, but decortication was used satisfactorily here. There were no respiratory studies as the objective was that of obliterating a small pleural space and sinus tract.

CASE 2.—F. W., a white man, aged 30 years. Onset of illness was discovered when patient was 14 years of age, on routine school survey in May, 1931, when x-ray and sputum examinations were both positive. Patient was treated on routine sanatorium care until 1936 when pneumothorax was established on the right side. He remained well and was working when the treatment was given up in 1941 and the lung was almost re-expanded in 1942. A sudden acute pleuritic episode in 1943 was accompanied by high fever and a massive effusion which responded to aspirations. It was noted that the lung would not completely re-expand. Following a period of well-being there was a similar complicating illness in March, 1947, and the fluid became thick and creamy by May. The sputum was negative but the pleural fluid was positive on culture. The patient was admitted for surgical treatment Sept. 29, 1947.

At bronchoscopy the right main bronchus was noted as slightly reduced in size and the upper lobe orifice reduced to about 20 per cent of normal.

A preliminary thoracoplasty was carried out in two stages with the removal of large segments of six ribs and was completed Nov. 10, 1947.

Decortication was done on Jan. 24, 1948, by removing a rib and entering the pleura through its bed. There were fluid, fibrin, and peel present. The middle and lower lobes peeled freely and the middle lobe appeared of about normal size.

A dense mass was palpated at the apical portion of the lower lobe and was interpreted as a healed lesion, and, therefore, not decorticated. Both lobes distended on pressure of the anesthetic bag. The postoperative course was uneventful, but re-expansion was only partial. Fluid re-formed and despite repeated aspiration and maintenance of high negative pressure the pleural space did not obliterate.

RESPIRATORY STUDIES, DEC. 15, 1947

	Determined		*Predicted*
Maximum Breathing Capacity	85 L/m		131 L/m
Lung Volume, Recumbent	*Determined*		*Predicted*
Total volume	3.80		4.74
Vital capacity	2.42		3.80
Mid capacity	1.90		1.72
Reserve air	0.52		0.78
Residual air	1.38 (37%)		0.94
Bronchospirometry	*Right Lung*		*Left Lung*
Minute ventilation	30%		70%
Oxygen consumption	20%		80%
CO_2 output	23%		77%
Vital capacity	21%		79%
Arterial Blood Gases (at rest)			
CO_2 content	47.77 vol. %		
O_2 content	19.06 vol. %	pCO_2	36 mm.
O_2 capacity	20.84 vol. %	pO_2	83 mm.
HbO_2 saturation	91%		
Calculated alveolar pO2 = 93 mm.			
Alveolar-arterial gradient = 10 mm.			
Arterial Blood Gases (during exercise on motor-driven treadmill, 8% grade, 2½ miles per hour)			
CO_2 content	45.40 vol. %		
O_2 content	18.71 vol. %	pCO_2	44 mm.
O_2 capacity	21.73 vol. %	pO_2	74 mm.
HbO_2	86%		
Calculated alveolar pO_2 = 95 mm.			
Alveolar-arterial gradient = 21 mm.			
Metabolic and Respiratory Response to Exercise*			
Minute ventilation			24.3 L.
Oxygen consumption			0.865 L.
CO_2 output			0.76 L.
O_2 ventilation equivalent			28 L.
Dyspnea index = .29			
Pulse rate (at height of exercise)			128/m
Pulse rate (at end of 10 minutes of recovery)			100/m
Respiratory rate (height of exercise)			22/m
Respiratory rate (at end of 10 minutes of recovery)			14/m

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*The exercise was carried out on the motor-driven treadmill at 2 miles per hour on a 4% grade for a duration of six minutes. Expired air was collected during the fifth and sixth minutes.

Respiratory Studies, March 31, 1948, Postdecortication

	Determined	*Predicted*
Maximum Breathing Capacity	94 L/m	133 L/m
Lung Volume, Recumbent	*Determined*	*Predicted*
Total volume	4.20	6.36
Vital capacity	2.94	5.10
Mid capacity	1.82	2.30
Reserve air	0.56	1.04
Residual air	1.26 (30%)	1.26

Lung Ventilation Efficiency

5 times F.R.A. = 86% (normal = 85% or more)

Bronchospirometry	*Right Lung*	*Left Lung*
Minute ventilation	29%	71%
Oxygen consumption	25%	75%
Carbon dioxide output	22%	78%
Vital capacity	21%	79%

Arterial Blood Gases (at rest)

CO_2 content	44.41 vol. %		
O_2 content	17.90 vol. %	pCO_2	33.6 mm. mercury
O_2 capacity	19.26 vol. %	pO_2	85.7 mm.
HbO_2 saturation	92.9%	pH	7.42 (immediate)

Calculated alveolar pO_2 = 85 mm.

Alveolar-arterial gradient = 5 mm.

Arterial Blood Gases (during exercise, 4% grade, 2 miles per hour)

CO_2 content	45.78 vol. %		
O_2 content	17.80 vol. %	pH	7.36 (immediate)
O_2 capacity	20.37 vol. %		
HbO_2 saturation	87.4%		

Metabolic and Respiratory Response to Exercise*

Minute ventilation	22.0 L.
Oxygen consumption	0.968 L.
CO_2 output	0.80 L.
O_2 ventilation equivalent	22.7 L.
Dyspnea index = .23	
Pulse rate (at height of exercise)	122
Pulse rate (at end of 10 minutes of recovery)	92
Respiratory rate (at height of exercise)	18
Respiratory rate (at end of 10 minutes recovery)	12

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*Exercise was carried out on motor-driven treadmill, 2 miles per hour, 4% grade, for duration of six minutes. Expired air was collected during fifth and sixth minutes.

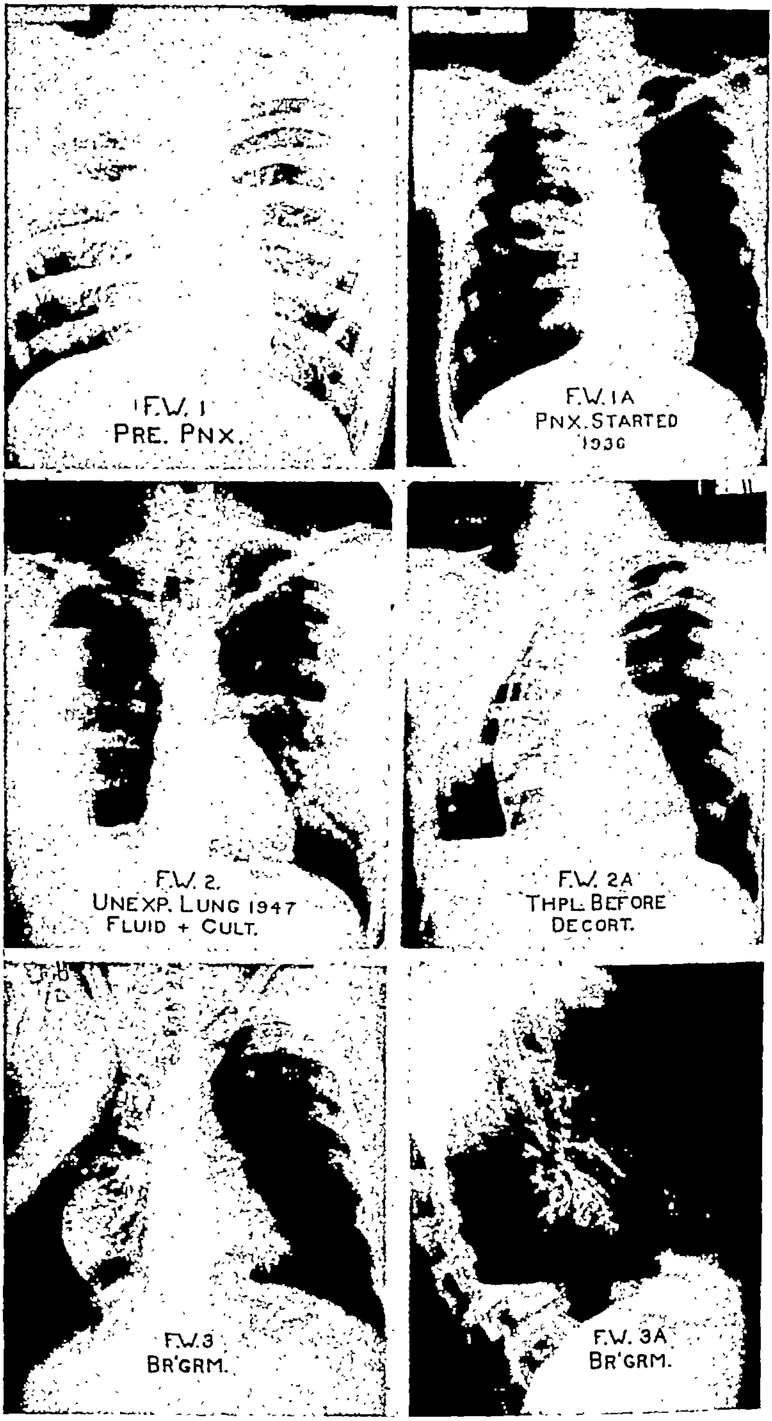

Fig. 3*A* (Case 2).—F. W. *1*, showing extent of pulmonary disease before pneumothorax. F. W. *1A*, film showing beginning pneumothorax and a better depiction of cavities. F. W. *2*, showing complicating pleural effusion in the presence of an incompletely expanded lung. F. W. *2A*, showing residual space after partial thoracoplasty. F. W. *3* and *3A*, bronchogram showing poor bronchial pattern for upper lobe, normal pattern of middle lobe, normal pattern for most of right lower lobe except for apical portion.

An additional stage of thoracoplasty with removal of three more ribs (10 in all) was done three months after decortication. There was further decrease of the pleural space at the time of discharge. The sputum remained negative and the postoperative fluid became negative.

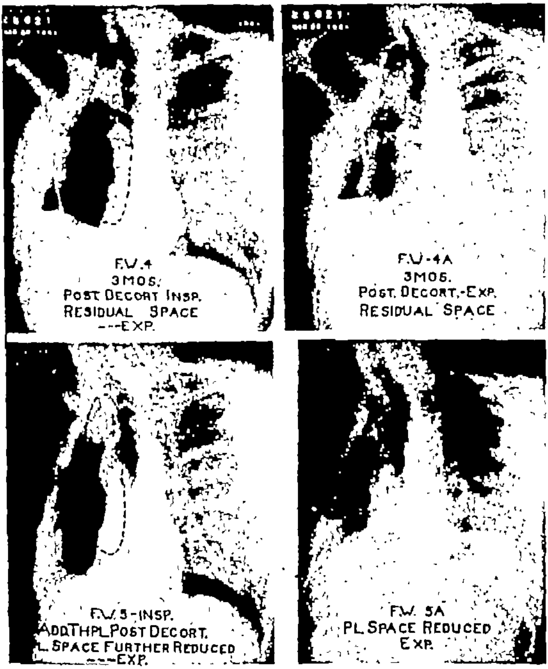

Fig. 3B (Case 2).—F. W. 4 and 4A, show partial further expansion of lung following decortication. Some residual space is still seen. Dotted line shows some decrease in size of lung in expiration, indicating some functional movement. F. W. 5 and 5A, showing further obliteration of residual pleural space by additional thoracoplasty. Dotted line indicates change in lung size in expiration.

Comment.—This was a typical case of long-standing pneumothorax and an unexpandable lung. There were repeated episodes of pleurisy with effusion, fever, and resulting empyema. Because of the extensive lung involvement before pneumothorax, it was thought that thoracoplasty should be done first to assure permanent collapse of the diseased and apparently healed portion of the lung. Some degree of arterial blood oxygen desaturation was recorded on exercise before decortication was done. After decortication, respiratory studies showed an increase in complementary air with an increase in mobility of the lung. The bronchospirometric readings remained unchanged and there was no improvement in the arterial hemoglobin saturation. It was then reasoned that the lung had already reached its limits of functional distensibility. Therefore, further pleural space obliteration would have to be aided by additional thoracoplasty. It is expected that complete obliteration will follow.

CASE 3.—H. S. was a white woman, 31 years of age, whose pulmonary tuberculosis was discovered at routine health checkup x-ray examination in November, 1938. Twelve days after sanatorium admission, pneumothorax was established on the right side and maintained thereafter. The patient became well and was discharged in 1940. Except for several intermittent attacks of pleurisy with effusion, she remained well until April, 1947, when disease was noted at the summit of the left lung and the right lung was recognized as unexpandable since no refills had been given for a very long time and no evidence of fistula was observed.

The patient was admitted for surgical care on Nov. 10, 1947. A bronchoscopic examination showed only slight generalized redness on the right side.

RESPIRATORY STUDIES, JAN. 14, 1948

		Determined		*Predicted*
Maximum Breathing Capacity		54 L/m		85 L/m
Lung Volume, Recumbent		*Determined*		
Total volume		2.00		
Vital capacity		1.25		
Mid capacity		1.00		
Reserve air		0.25		
Residual air		0.75 (38%)		
Lung Ventilation Efficiency				
5 times F.R.A. = 75% (normal = 85% or more)				
Bronchospirometry		*Right Lung*		*Left Lung*
Minute ventilation		14%		86%
Oxygen consumption		9%		91%
Vital capacity		6%		94%
Arterial Blood Gases During Exercise				
CO_2 content	39.28 vol. %			
O_2 content	17.55 vol. %			
O_2 capacity	18.89 vol. %		pCO_2	37 mm. mercury
HbO_2 saturation	93%		pO_2	89 mm. mercury
Calculated alveolar pO_2				106 mm.
Alveolar-arterial gradient				17 mm.
Metabolic and Respiratory Response to Exercise*				
Minute ventilation				27.5 L.
Oxygen consumption				0.78 L.
CO_2 output				0.75 L.
O_2 ventilation equivalent = 35 L.				
Dyspnea (by complaint) 1 plus				
Dyspnea index = .51				

*On motor-driven treadmill at 2.5 miles per hour, 4% grade.

Because of the extensive pulmonary disease before pneumothorax and recent contralateral disease it was elected to do a two-stage, seven-rib thoracoplasty which was completed Dec. 22, 1947. The decortication was carried out on March 18, 1948, when fluid, fibrin, and peel were seen and removed. Nodular areas were seen and palpable. The middle lobe was about normal in size and the lower lobe was reduced in size, but the lower part inflated satisfactorily. A portion of the lower anterior part of the upper lobe was also peeled free. The postoperative course was uneventful and the pleural space became obliterated.

Comment.—Pneumothorax for very extensive pulmonary disease resulted in healing and an unexpandable lung. There were the usual pleural fluid complications in a dead space with contralateral reactivation as mediastinal shift developed. Satisfactory obliteration of pleural space was achieved by a combination of thoracoplasty and decortication. The contralateral lesion also healed or regressed and sputum remained negative.

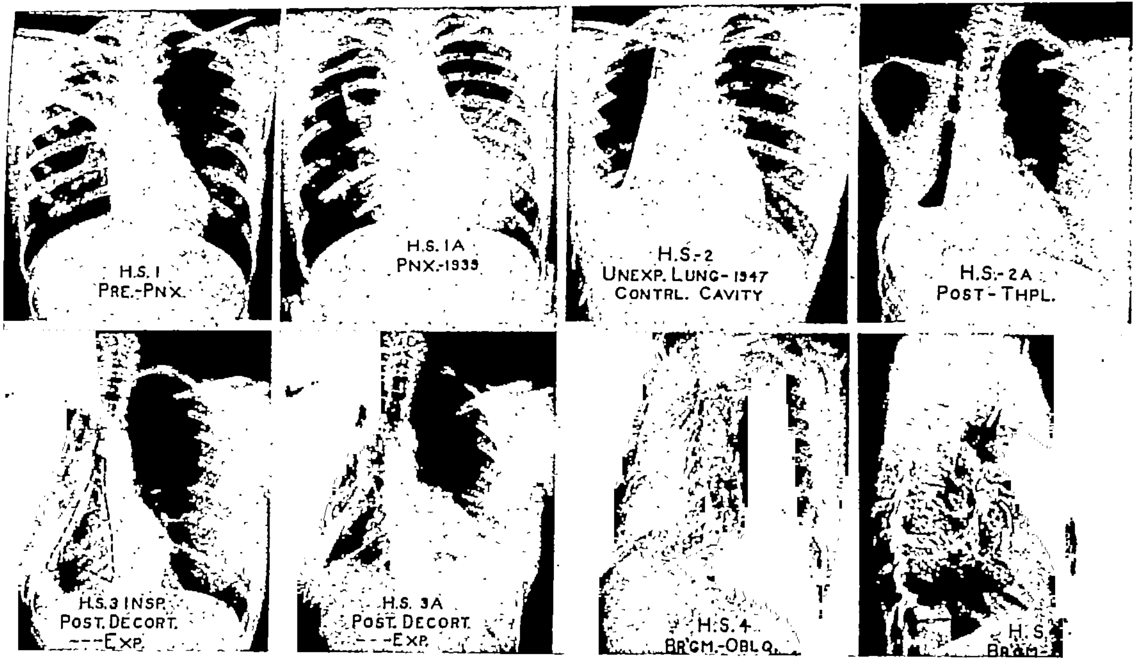

Fig. 4 (Case 3).—H. S. *1*, showing extent of pulmonary disease before pneumothorax. H. S. *1A*, showing partial pneumothorax with giant-sized cavity in upper lobe and some disease in the lower. H. S. *2*, showing unexpandable lung after eight years of pneumothorax. H. S. *2A*, showing residual pleural space following thoracoplasty. H. S. *3* and *3A*, show obliteration of pleural space following decortication. Dotted line compares size of lung on expiration with inspiration. H. S. *4* and *4A*, bronchograms showing relatively poor bronchogram except lower lobe, and a portion of middle lobe.

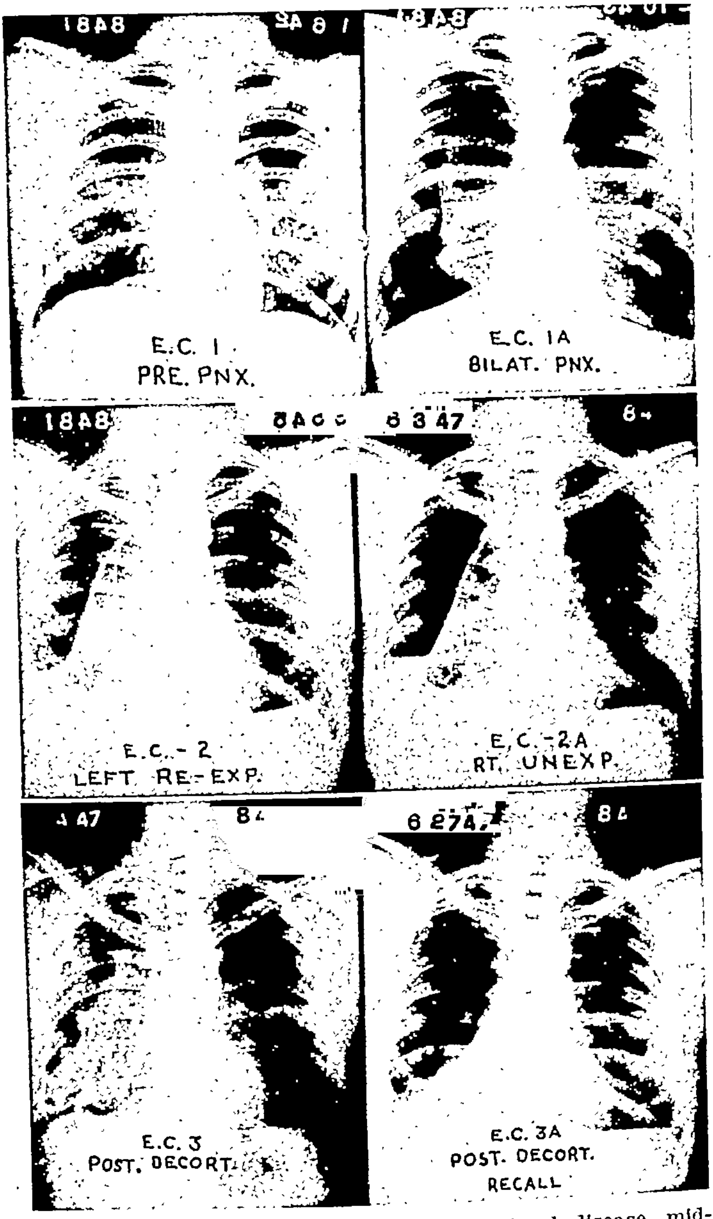

Fig. 5A (Case 4).—E. C. *1*, showing extent of bilateral disease, mid-zone of lung on each side. E. C. *1A*, showing bilateral pneumothorax. E. C. *2*, showing left lung re-expanded with fluid in pneumothorax continued on right. E. C. *2A*, right lung now unexpandable with fluid in pleural space. E. C. *3*, early postoperative film showing almost complete expansion of right lung following decortication. E. C. *3A*, showing spontaneous recollapse of right lung.

CASE 4.—E. C., a 23-year-old white man, a veteran, was found to have pulmonary tuberculosis on a routine x-ray film taken in May, 1942, for service transfer. Pneumothorax was instituted on the left in November, 1942, and discontinued by re-expansion in March, 1945. The right side was also treated by pneumothorax begun in February, 1943, and complicated by tuberculous empyema in February, 1944. Efforts at re-expansion failed and bronchos-

RESPIRATORY STUDIES, MARCH 1, MARCH 3, AND APRIL 3, 1947, PREDECORTICATION

	Determined	*Predicted*
Maximum Breathing Capacity	74 L/m	126 L/m
Lung Volume, Recumbent	*Determined*	*Predicted*
Total volume	2.92	5.14
Vital capacity	1.84	3.88
Mid capacity	1.32	1.94
Reserve air	0.24	0.68
Residual air	1.08 (37%)	1.26
Lung Ventilation Efficiency		
5 times mid capacity = 65% (normal = 85% or more)		
Bronchospirometry	*Right Lung*	*Left Lung*
Minute ventilation	27%	73%
Oxygen consumption	18%	82%
CO_2 output	15%	85%
Vital capacity	34%	66%

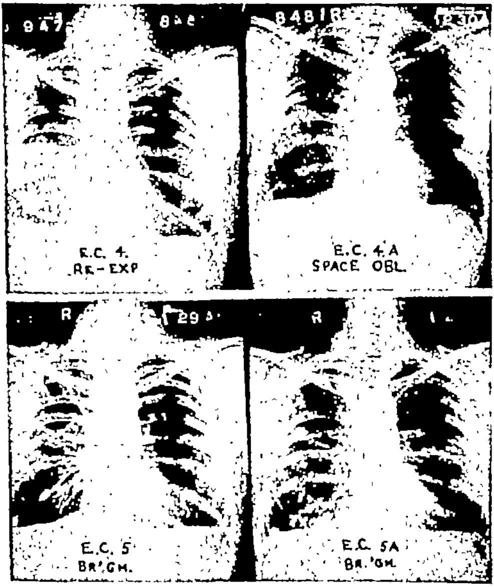

Fig. 5B (Case 4).—E. C. 4, showing right lung again re-expanding. E. C. 4A, right pleural space completely obliterated. E. C. 5 and 5A, bronchogram showing incomplete bronchial pattern especially of middle zones which were the site of previous pulmonary disease (see E. C. 1).

copy showed only slight distortion of the bronchial tree secondary to pulmonary collapse. The sputum was negative for tubercle bacilli and decortication was carried out on June 12, 1947. Early in the postoperative course re-expansion was noted as occurring but this was complicated by sudden collapse of the lung associated with a positive pressure. This was thought to be secondary to spontaneous lung rupture. Ultimately there was re-expansion or, more correctly, loss of the pneumothorax space. In this instance, however, as may be seen from the physiological studies, the function was further decreased.

RESPIRATORY STUDIES, DEC. 16, 1947, POSTDECORTICATION

	Determined	*Predicted*
Maximum Breathing Capacity	70 L/m	129 L/m.
Lung Volume, Recumbent	*Determined*	*Predicted*
Total volume	3.77 L.	5.14 L.
Vital capacity	2.32	3.88
Mid capacity	1.64	1.94
Reserve air	0.19	0.68
Residual air	1.45 (38.4%)	1.26
Lung Ventilation Efficiency		
5 times mid capacity = 69% (normal = 85% or more)		
Bronchoscospirometry	*Right Lung*	*Left Lung*
Minute ventilation	32%	68%
Oxygen consumption	25%	75%
CO_2 output	22%	78%
Vital capacity	36%	64%
Arterial Blood Gases (at rest)		
CO_2 content	49.69 vol. %	
O_2 content	18.16 vol. %	pCO_2 31 mm. mercury
O_2 capacity	20.91 vol. %	pO_2 64 mm. mercury
HbO_2 saturation	87%	
Calculated alveolar pO_2	98 mm.	
Alveolar-arterial gradient	34 mm.	

Comment.—This is a most interesting case and serves to suggest the possible undesirable effects which might follow primary decortication. There was bilateral disease with bilateral pneumothorax treatment which was successful on the left but complicated by fluid and an unexpandable lung on the right. The postdecortication incident of superimposed spontaneous pneumothorax suggests the rupture of an emphysematous bleb. Ultimate obliteration of the hydropneumothorax was accomplished. This, however, was followed by increase in lung volume but decrease in lung function. There may have resulted shunting of blood in poorly ventilated area or the further development of emphysema in the re-expansion. The bronchogram shows poor patterns on both sides which are secondary to parenchyma changes.

CASE 5.—S. H. was a white woman 38 years of age. The onset of the disease was in May, 1939. Pneumothorax left started two weeks later. Fluid formed in October, 1939, and treatment was continued until 1941, when an attempt was made to re-expand the lung, including the use of oxygen lavage. The patient was rehospitalized in February, 1943, when fluid on the right was found to contain tubercle bacilli. In August, 1943, pneumothorax was started on left side and later re-expanded, but was reinduced September, 1944, because of recurring symptoms.

At the present hospitalization there was a poor, nonselective pneumothorax on the left and an unexpandable lung on the right complicated by tuberculous effusion. It was elected to do a small apical thoracoplasty on the left to collapse the diseased portion of the lung permanently and abandon the pneumothorax for fear of bilateral complications. This was done on the left on Nov. 24, 1947, and a primary decortication was done on the right Feb. 7, 1948.

RESPIRATION STUDIES, OCT. 20, 1947, BEFORE OPERATION

	Determined		*Predicted*
Maximum Breathing Capacity	58 L/m		70 L/m
Lung Volume, Recumbent	*Determined*		*Predicted*
Total volume	1.68		3.70
Vital capacity	1.17		2.65
Mid capacity	0.75		1.65
Reserve air	0.24		0.60
Residual air	0.51 (31%)		1.05
Lung Ventilation Efficiency			
5 times F.R.A. = 74% (normal = 85% or more)			
Bronchospirometry	*Right Lung*		*Left Lung*
Minute ventilation	41%		59%
Oxygen consumption	33%		67%
CO_2 output	36%		64%
Vital capacity	33%		67%
Arterial Blood Studies (at rest)			
CO_2 content	49.44 vol. %		
Oxygen content	16.85 vol. %		
Oxygen capacity	18.04 vol. %	pCO_2	38 mm.
Hbg saturation	93%	pO_2	75 mm.
Calculated alveolar pO_2	94 mm.		
Alveolar-arterial gradient	99 mm.		

RESPIRATORY STUDIES APRIL 27, 1948, ALMOST THREE MONTHS AFTER DECORTICATION

	Determined		*Predicted*
Maximum Breathing Capacity	55 L/m		71 L/m
Lung Volume, Recumbent	*Determined*		*Predicted*
Total volume	1.57		*Not done*
Vital capacity	1.02		
Mid capacity	0.72		
Reserve air	0.17		
Residual air	0.55 (35%)		
Lung Ventilation Efficiency			
4.45 times F.R.A. = 82% (normal = 85% or more)			
Bronchospirometry	*Right Lung*		*Left Lung*
Minute ventilation	38%		62%
Oxygen consumption	30%		70%
CO_2 output	32%		68%
Vital capacity	30%		70%
Alveolar-Arterial Gradient (at rest)			
CO_2 content	43.22 vol. %		
O_2 content	16.37 vol. %	pCO_2	26 mm.
O_2 capacity	17.29 vol. %	pO_2	81 mm.
HbO_2 saturation	94.7%	pH	7.47

Comment.—This case presented a bilateral therapeutic problem treated with bilateral pneumothorax and resulting in an unexpandable right lung with pneumothorax present over eight years and complicating tuberculous fluid which would not resorb under usual treatment. Decortication failed to decrease appreciably the size of pleural space or improve lung function. In considering the over-all picture, the extent of the disease before the right pneumothorax and

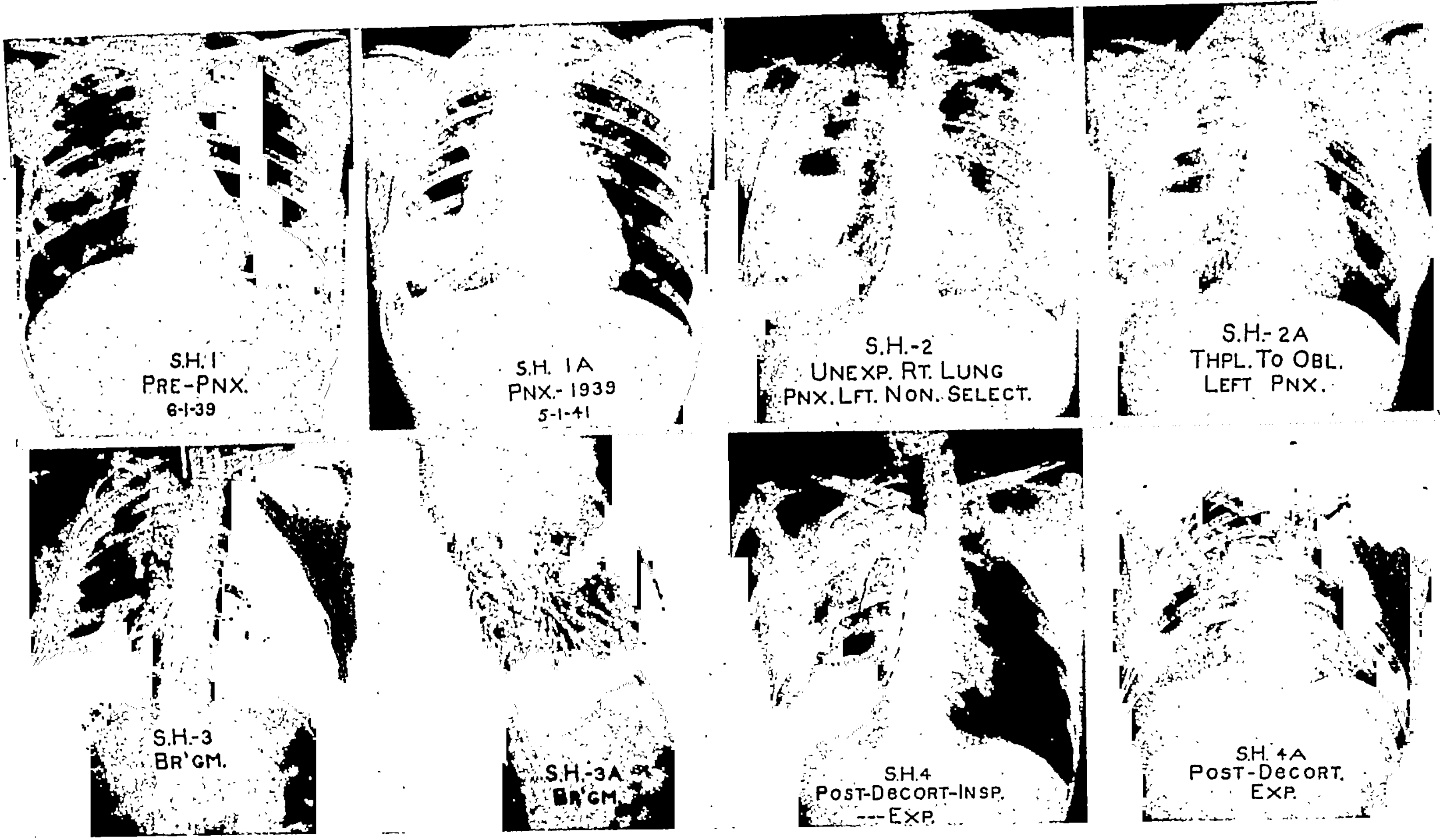

Fig. 6 (Case 5).—S. H. *1*, showing extent of pulmonary disease through right lung before pneumothorax was instituted. S. H. *1A*, showing presence of pneumothorax right, spread of disease to left coincident with attempt at re-expansion of right lung. S. H. *2*, showing unexpandable lung right, marked thickening of both pleural surfaces, fluid present, poor anatomical collapse by pneumothorax on left. S. H. *2A*, showing one stage of thoracoplasty left, with obliteration of pneumothorax and satisfactory collapse of diseased portion of this lung. Right, no change. S. H. *3* and *3A*, bronchograms showing relatively poor pattern throughout most of lung. S. H. *4* and *4A*, show slight further re-expansion of right lung following decortication. The dotted line compares expiration lung size with inspiration.

Note.—This patient has since had complete obliteration of right pleural space following partial thoracoplasty on the right.

the poor pattern shown by the bronchogram before decortication, it is not surprising that the respiratory studies showed no appreciable change. This was interpreted as suggesting that the limit of functional distensibility of the right lung had been reached. Such a case should, therefore, have a thoracoplasty added to aid in obliterating the remaining pleural space. This was done.

CASE 6.—K. W. was a white man, a veteran, 24 years of age, the onset of whose disease was discovered on routine discharge x-ray film, July, 1945. Pneumothorax was induced shortly thereafter in the same month. During the course of collapse therapy, fluid developed which was positive for tubercle bacilli. Efforts at re-expansion failed and two stages of thoracoplasty were carried out during February and March, 1947. At bronchoscopy only slight narrowing of the left main bronchus was noted. No bronchial disease or stenosis was visible.

RESPIRATORY STUDIES, APRIL, 1947, PREDECORTICATION

	Determined	*Predicted*
Maximum Breathing Capacity	86 L/m	151 L/m
Lung Volume, Recumbent	*Determined*	*Predicted*
Total volume	3.22 L.	5.15 L.
Vital capacity	2.40	3.89
Mid capacity	1.10	1.94
Reserve air	0.30	0.68
Residual air	0.80 (24.9%)	1.26
Bronchospirometry: Left lung entirely nonfunctioning.		
Response to Six-Minute Walk at Level Grade on Treadmill at 3 M.P.H.		
Minute ventilation	39.75 L.	
Oxygen ventilation equivalent	32.30 L.	
Dyspnea index	.46	
Dyspnea = +		
Hyperpnea = +		
Gas Tensions, Resting		
	PO_2	*PCO_2*
Arterial blood	81 mm.	30 mm. mercury
Alveolar air	70 mm.	40 mm.
Alveolar air (calculated)	94 mm.	
Gas Tensions, Exercise*		
	PO_2	*PCO_2*
Arterial blood	61 mm.	44 mm.
Alveolar air (calculated)	93 mm.	
Hemoglobin Saturation* = 93%.		

*Level walk at 3.5 m.p.h.

RESPIRATORY STUDIES, JUNE 25, 1947, JULY 8, 1947, AND JULY 9, 1947, POSTDECORTICATION

	Determined	*Predicted*
Maximum Breathing Capacity	80 L/m	151 L/m
Lung Volume, Recumbent		
Total volume	3.11	5.15
Vital capacity	2.14	3.89
Mid capacity	1.17	1.94
Reserve air	0.18	0.68
Residual air	0.97 (31%)	1.26
Bronchospirometry	*Right Lung*	*Left Lung*
Minute ventilation	100%	
Oxygen consumption	100%	
CO_2 output	100%	
Vital capacity	100%	

A decortication was done on May 18, 1947, for the purpose of obliterating the remaining empyema space. At that time it was discovered that the lower lobe was not only completely collapsed but contained numerous tuberculous nodules. The cortical peel was therefore only partially removed. This was followed by obliteration of the residual pleural space.

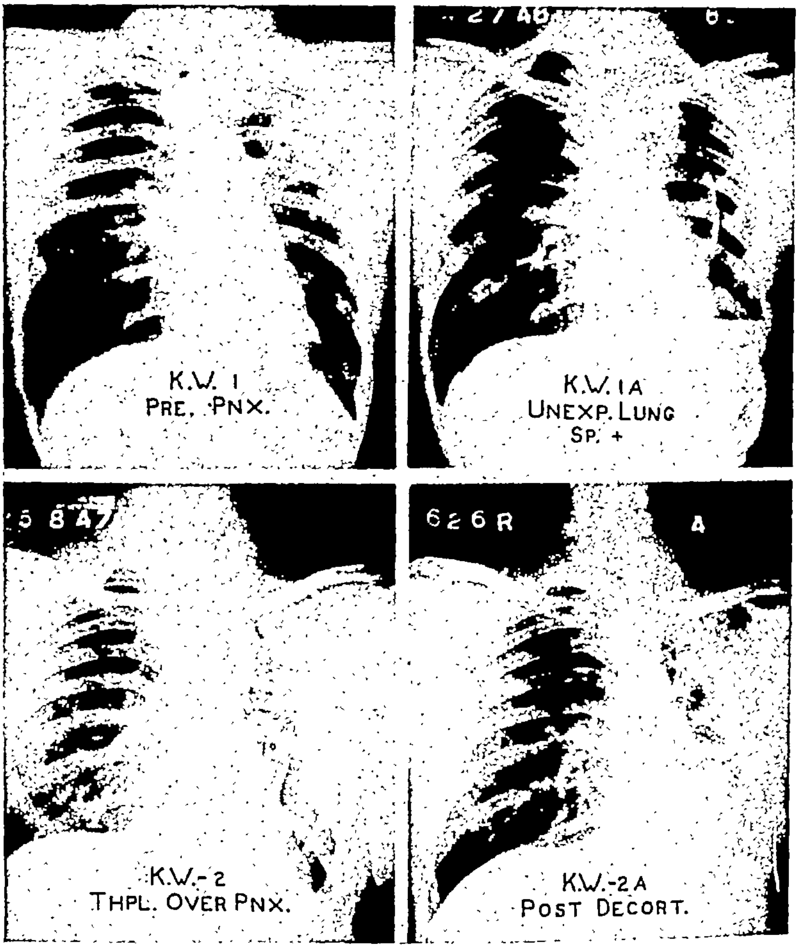

Fig. 7 (Case 6).—K. W. *1*, showing extent of pulmonary disease in left lung before pneumothorax. K. W. *1A*, showing pneumothorax, left lung unexpandable, fluid present. K. W. *2*, showing thoracoplasty left, with residual pleural space. K. W. *2A*, showing complete obliteration of pleural space following decortication.

Comment.—An unexpandable and functionless left lung was noted following pneumothorax treatment complicated by tuberculous empyema. The combination of thoracoplasty and decortication, though not resulting in functional improvement, has solved this problem without resorting to Schede operation.

CASE 7.—P. R. was a white man, aged 33 years.

Past History.—The patient had infantile paralysis at 5 or 6 years of age and there is a residual flaccid deformity of the right shoulder and upper extremity. In 1930 there was a midthoracic spine fusion for a nontuberculous condition.

Present History.—Onset of pulmonary tuberculosis was discovered by x-ray examination in September, 1946, and pneumothorax was instituted on the right in May, 1947. At admission in June, 1947, there was an irregular collapse but the sputum was reported negative and the established treatment was continued. In October, 1947, pleural fluid formed and with abandonment of the pneumothorax it was observed that the lung would not re-expand.

A two-stage thoracoplasty with removal of large segments of six ribs was completed Dec. 22, 1947. Bronchoscopy showed normal airways.

Decortication was done Jan. 28, 1948. There was clear fluid present and the cortical peel was easily removed from the lower and middle lobes. The collapsed upper lobe was not

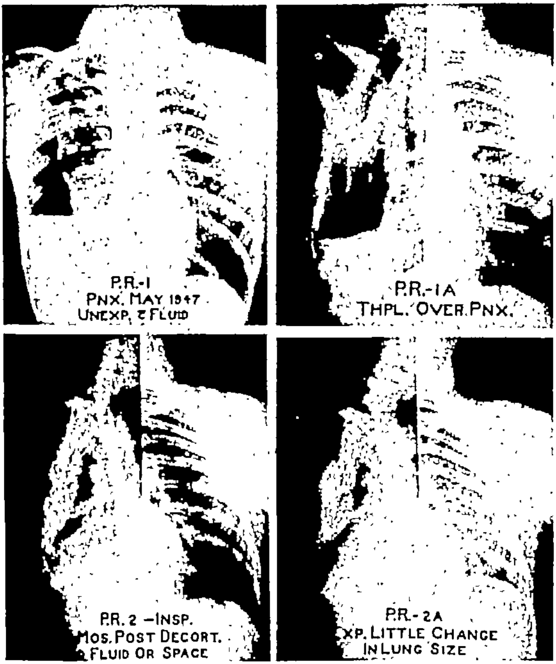

Fig. 8 (Case 7).—P. R. *1*, showing unsatisfactory pneumothorax, lung unexpandable, fluid present. P. R. *1A*, showing primary thoracoplasty with collapse of underlying diseased lung, residual pleural space remaining. P. R. *2* and *2A*, showing obliteration of pleural space following decortication, very slight change in lung size in expiration.

RESPIRATORY STUDIES, JAN. 5, 1948

		Determined	*Predicted*
Maximum Breathing Capacity		58 L/m	106 L/m
Lung Volume, Recumbent		*Determined*	*Predicted*
Total volume		2.10	4.00
Vital capacity		1.37	3.21
Mid capacity		1.09	1.45
Reserve air		0.36	0.66
Residual air		0.73 (35%)	0.79
Arterial Blood at Rest			
CO_2 content	50.57 vol. %	HbO_2 saturation	89%
O_2 content	17.13 vol. %	pCO_2	41 mm.
O_2 capacity	19.33 vol. %	pO_2	68 mm.
Calculated alveolar pO_2	87 mm.		
Alveolar-arterial gradient	19 mm.		

RESPIRATORY STUDIES, MAY 26, 1948, POSTDECORTICATION

	Determined		*Predicted*
Maximum Breathing Capacity	59 L/m		107 L/m
Lung Volume, Recumbent	*Determined*		*Predicted*
Total volume	2.52		4.84
Vital capacity	1.54		3.88
Mid capacity	1.36		1.75
Reserve air	0.38		0.79
Residual air	0.98 (39%)		0.96
Lung Ventilation Efficiency			
5 times F.R.A. = 72% (normal = 85% or more)			
Bronchospirometry	*Right Lung*		*Left Lung*
Minute ventilation	18%		82%
Oxygen consumption	12%		88%
CO_2 output	9%		91%
Vital capacity	10%		90%
Alveolar-Arterial Gradient (at rest)			
CO_2 content	52.06 vol. %		
O_2 content	17.86 vol. %	pCO_2	43 mm.
O_2 capacity	19.64 vol. %	pO_2	72 mm.
HbO_2 saturation	90.9%	pH	7.42 mm.

decorticated. The two lower lobes distended when pressure was applied to the anesthetic bag but for some reason the color remained slate blue instead of becoming pink. The postoperative course was uneventful.

Comment.—This was the earliest decortication in point of time. From the establishment of pneumothorax and development of pleural complications there were just seven months. The operation was easy to do and the peel showed tubercle formation. There was a virtually nonfunctioning lung which showed slight gain in function four months postdecortication with satisfactory obliteration of the pleural space. A preliminary thoracoplasty was done to avoid the risk of reactivation of recently collapsed active disease in the lung.

CASE 8.—J. Sc. was a white man, aged 47 years, the onset of whose present illness is dated to an attack of pleurisy with effusion in 1920. There was a seventeen-day period of hospitalization during which time one chest aspiration was done. Relief was obtained and at discharge the patient was advised to "go to the country" to rest. This was done for three months, after which he returned to the city and was perfectly well thereafter. In 1941 a hemorrhoidectomy was done because of bleeding and there was a five-day hospital stay. Two months later his physician told the patient that the removed tissue was reported as tuberculous and the patient was advised to attend a chest clinic. This he did but was told after x-ray examination of the chest to "take things easy." In May, 1942, he entered a hospital where roentgenograms were again taken of the chest and after ten days he was transferred elsewhere. There was some cough, expectoration, and fever. After three months he was discharged. The patient worked full time as a shirt presser until 1947 when increasing fatigue, cough, and expectoration made him seek medical care. He was then advised to seek sanatorium care. At admission there was evidence of a calcified pleura, air and fluid in the right pleural space, and a small antrum in the summit of the left lung. Tuberculous empyema was proved as well as an intermittent bronchopleural fistula and a positive sputum. A bronchoscopic examination showed no abnormalities.

Operation.—Decortication was carried out on April 24, 1948. This operation was more difficult than any of the others. Only small areas could be peeled free as contrasted to large placques in other cases. There were multiple tiny fistulous leaks and the underside (lung side)

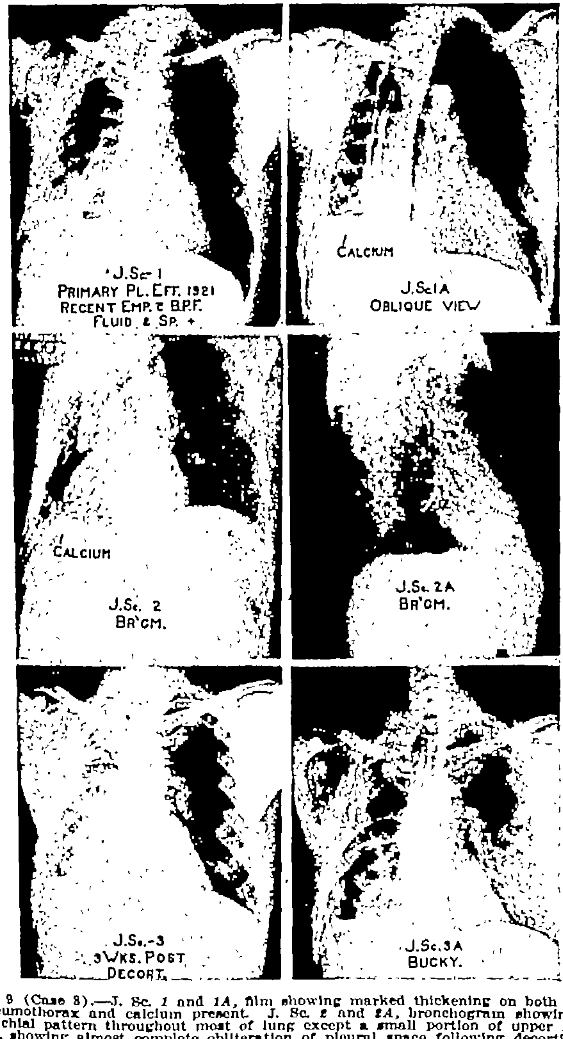

Fig. 9 (Case 8).—J. Sc. *1* and *1A*, film showing marked thickening on both pleural surfaces, pneumothorax and calcium present. J. Sc. *2* and *2A*, bronchogram showing relatively good bronchial pattern throughout most of lung except a small portion of upper lobe. J. Sc. *3* and *3A*, showing almost complete obliteration of pleural space following decortication. "S" line is not the limiting margin of pleural space.

Respiratory Studies, March 24, 1948

	Determined	Predicted
Maximum Breathing Capacity	55 L/m	105 L/m
Lung Volume, Recumbent	*Determined*	*Predicted*
Total volume	2.74	4.54
Vital capacity	1.53	3.64
Mid capacity	1.43	1.65
Reserve air	0.22	0.75
Residual air	1.21 (44%)	0.90
Lung Ventilation Efficiency		
5 times F.R.A. = 59% (normal = 85% or more)		
Bronchospirometry	*Right Lung*	*Left Lung*
Minute ventilation	18%	82%
Oxygen consumption	11%	89%
CO_2 output	9%	91%
Vital capacity	15%	85%
Arterial Blood Gases (at rest)		
CO_2 content	50.66 vol. %	
O_2 content	17.18 vol. %	
O_2 capacity	18.72 vol. %	
HbO_2 saturation	91.8%	
Arterial Blood Gases During Exercise*		
CO_2 content	47.81 vol. %	
O_2 content	15.85 vol. %	
O_2 capacity	19.69 vol. %	
HbO_2 saturation	80.5%	
Metabolic and Respiratory Response to Exercise†		
Minute ventilation	37.9 L.	
Oxygen consumption	1.29 L.	
CO_2 output	1.13 L.	
Oxygen ventilation equivalent = 29.4 L.		
Dyspnea index = .69		
Pulse rate (at height of exercise)		142/m
Pulse rate (after 10 minutes of recovery)		96/m
Respiratory rate (at height of exercise)		42/m
Respiratory rate (at end of 10 minute recovery)		25/m

*4% grade at 3 m.p.h.

†The patient was walked at a level, 4% and 6% grades at 3 miles per hour. On the 6% grade, he walked for six minutes and expired air was collected during the fifth and sixth minutes.

of the peel had a strawberry-like appearance. When the lung had been peeled free and pressure was applied to the anesthetic bag, inflation occurred and the lung took on a pink color, but there was some scarring and dimpling.

Postoperatively there was evidence of expansion but incomplete obliteration of the pleural space. It is too early in the postoperative period to predict the ultimate outcome. The plan is to repeat the respiratory studies in this case at a later date when re-expansion may be complete or no further change noted.

Comment.—This is the oldest case in point of time elapsed (26 years) since the onset of pleural disease. There was little to suggest the extent of pulmonary involvement and in addition the pleura was calcified and intermittently a bronchopleural fistula was demonstrated clinically though not seen at operation. The outcome must be awaited.* It was shown that though difficult of performance, the operation could be done.

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*Respiratory studies six months postdecortication showed functional improvement particularly noted in a good HbO_2 saturation after exercises (93.1 per cent).

CASE 9.—R. T. was a Hawaiian-Japanese physician, 30 years of age, whose pulmonary tuberculosis was discovered during hospital residency elsewhere in the winter of 1945, and pneumothorax was instituted in December, 1945. This was complicated by the formation of fluid in May, 1946, associated with fever. Empyema developed and was treated conservatively by aspiration and irrigation. There was marked "pleural thickening" so that a 2½ inch needle had to be put in all the way for removal of fluid. With more frequent pleural lavage and instillation of large amounts of penicillin there was ultimate complete re-expansion of the lung. Function is virtually restored as noted clinically by normal breath sounds and good movement in inspiration and clouding or emptying on expiration.

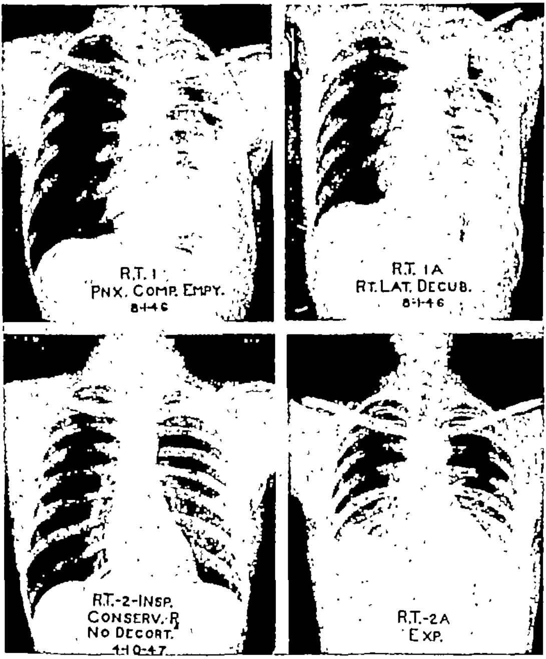

Fig. 10 (Case 9).—R. T. *1* and *1A*, Showing marked thickening on both pleural surfaces, lung unexpandable. R. T. *2* and *2A*, lung re-expanded to normal size. Good function is noted by expiration showing satisfactory emptying of left lung and complete resolution of both pleural peels.

Note.—This case was not treated by decortication.

Comment.—The patient had a small amount of lung involvement resulting in severe loss of function by the empyema complication and markedly thickened "peel." Resolution of the peel and return to function of the lung occurred without decortication. This suggests that with a good underlying lung the prospect of re-expansion and return to good function is excellent even when decortication is not carried out.

CONCLUSIONS

Decortication suggests itself for the following conditions at the present time: (1) longstanding inexpansible pneumothorax; (2) persisting hydro- or pyopneumothorax which fails to respond to other measures; (3) re-expansion of a contraselective collapse of healthy lung; (4) instead of a Schede operation in pleurocutaneous fistula with residual pleural space (possibly in the presence of a bronchopleural fistula also).

Thus far the material studied indicates that empyema is not a deterrent in performing the operation and obtaining primary wound healing.

As much improvement in function need not follow decortication in tuberculosis as is seen in uncomplicated cases of hemothorax or pyothorax. There is some suggestion that decreased arterial oxygen saturation might result.

It is suggested that a carefully planned study both before and after operation, as well as a long-term follow-up, be undertaken before the place for decortication in tuberculosis is established in our armamentarium.

REFERENCES

1. Gurd, F. B.: Decortication in Chronic Empyema of Tuberculous Origin, J. THORACIC SURG. 16: 587, 1947.
2. Langston, H. T., and Tuttle, W. M.: The Pathology of Chronic Traumatic Hemothorax, J. THORACIC SURG. 16: 99, 1947.
3. Tuttle, W. M., Langston, H. T., and Cromley, R. T.: The Treatment of Organizing Hemothorax by Pulmonary Decortication, J. THORACIC SURG. 16: 117, 1947.
4. Samson, P. C., and Burford, T. H.: Total Pulmonary Decortication, Its Evolution and Present Concepts of Indications and Operative Technique, J. Thoracic Surg. 16: 127, 1947.
5. Mulvihill, D. A.: Discussion of Gurd,[1] p. 597.
6. Curreri, A. R., and Gale, J. W.: Decortication in the Treatment of Chronic Empyema, Arch. Surg. 55: 486, 1947.
7. Lam, C. R.: Decortication of the Lung in the Treatment of Tuberculous Empyema, Arch. Surg. 56: 1, 1948.
8. Vorwald, A. J.: Personal communication.
9. Bruns, O.: Quoted by Gardner,[10] and Pinner.[11]
10. Gardner, L. U.: The Pathology of Artificial Pneumothorax in Pulmonary Tuberculosis, Am. Rev. Tuberc. 10: 501, 1925.
11. Pinner, M.: in Alexander, J.: The Collapse of Pulmonary Tuberculosis, Springfield, Ill., 1937, Charles C Thomas, chap. IV, Pathology of Pulmonary Collapse, p. 69.
12. Wright, G. W., Yee, L. B., Filley, G. F., and Stranahan, A.: Physiologic Observations Concerning Decortication of the Lung, J. THORACIC SURG. 18: 372, 1949.

(*See discussion on page 385.*)

DECORTICATION OF THE UNEXPANDED TUBERCULOUS LUNG FOLLOWING PNEUMOTHORAX

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TWO years ago Gurd[1] presented before this association a report on the successful outcome of three operations of decortication in tuberculous empyema. This was of momentous importance since it had been previously considered that tuberculosis was one of the definite contraindications to decortication in pleural empyema. At the same meeting Mulvihill,[2] in discussing Gurd's presentation, reported the successful decortication of a nonexpanding tuberculous lung following therapeutic pneumothorax. During the past eight months we have performed the operation on seven patients with this latter type of disease, and it is these cases which we now wish to discuss.

Tuberculous empyema and unexpanded tuberculous lung following pneumothorax do not differ greatly in the nature of the pathology and in the progression of the disease. In some cases it is possible to differentiate the two clinically only by the content of the pleural space, and oftentimes there is lack of agreement on this basis. In general, the fluid is thinner in "unexpanded lung" and the pleural space may frequently become obliterated by properly directed therapy; but as long as the space persists, there is the threat of conversion to an empyema which will require drainage or other surgical therapy.[3, 4] Even though the space is eventually obliterated, it is largely through shifting of the mediastinal structures, elevation of the diaphragm and narrowing of the intercostal spaces, and very little through expansion of the homolateral lung.

Thus, in most cases of long-standing unexpanded lung, the patient is threatened with serious possibilities, the formation of a tuberculous empyema or the impairment of the functions of respiration and circulation incident to the extreme shifting of the mediastinal structures. It is for these reasons that decortication is desirable if it can be accomplished with safety.

What are the possible objections to decortication? The greatest concern is that the tuberculous disease will be activated by the trauma of operation and the too early expansion of the diseased lung. In none of our cases has activation or spread of tuberculosis occurred following operation. Streptomycin, which is given during the surgical period, may well be the responsible factor. One gram is given daily in divided doses for not less than five days preceding surgery and for not less than ten days following surgery. Studies with the use of streptomycin in other types of surgery in pulmonary tuberculosis indicate that a dosage of 1 Gm. daily is adequate for prophylaxis against spread during the surgical period.

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A sufficient number of cases of decortication in tuberculous empyema has now been reported to prove that the operation may be performed safely.[1, 2, 5] The main questions to be answered now are, "In which cases should the operation be performed?" and "How frequently will the surgeon be thwarted when decortication is attempted?" Several thoracic surgeons[6, 7, 8] have sounded notes of warning that one should exercise considerable caution in recommending the procedure in tuberculous empyema. They have particularly emphasized the danger of permitting the underlying diseased lung to re-expand. Our experience does not support this apprehension. The compression of the underlying pulmonary tissue by encasement of the lung in a tuberculous membrane is hardly an effective means of healing a tuberculous lesion. The compression should be performed selectively according to plan. One has only to examine the greatly thickened and indurated membrane, particularly at the apex, to realize the futility of attempts at selective compression by thoracoplasty or other means as long as the membrane is present. We consider it more logical to remove the tuberculous membrane, permit the lung to expand if it will do so, and later perform the indicated compression therapy in a purposeful manner. Thoracoplasty has been performed after decortication in two of our cases, and is contemplated in another.

With regard to the technical features, all of our cases have been operated upon through an intercostal incision without resection or division of a rib. This means of entering the thorax and obtaining wide exposure is possible even though the ribs overlap each other. This is contrary to the general impression that it is necessary to resect a number of ribs in order to obtain sufficient exposure. The fifth interspace is usually selected, but satisfactory exposure has also been obtained through the fourth and sixth interspaces.

It has been possible to remove all or almost all of the diseased membrane in the cases operated upon thus far (Fig. 1). Oddly enough, it appears that decortication is easier if the parietal membrane is included in the resection. As soon as the parietal pleura is exposed, it is separated from the thoracic wall over the distance of two or three ribs. The retractor blades are then separated widely, the sac is opened to permit evacuation of its contents and the separation of the parietal layer is continued in all directions. As the dissection progresses from the parietal to the visceral surface, one finds a plane of separation at the thickened ring which marks the junction between the parietal and visceral membranes (Fig. 2). In our earliest operations, this feature was not recognized and separation of the visceral pleura was accomplished with difficulty. In three later cases, it was possible to remove the entire membrane in a single cast. There are other important reasons for including the parietal membrane in the resection. Its removal from the costal, diaphragmatic, and other surfaces which may be involved, as well as from the visceral surface, will help to restore the function of the released lung by permitting increased excursions of the thoracic wall and diaphragm. Furthermore, a source of toxic absorption is thus removed. We are also of the opinion that sinus formations in the thoracic wall may follow incomplete removal as the result of extension of infection from the remaining membrane. Primary healing followed operation in all of our cases.

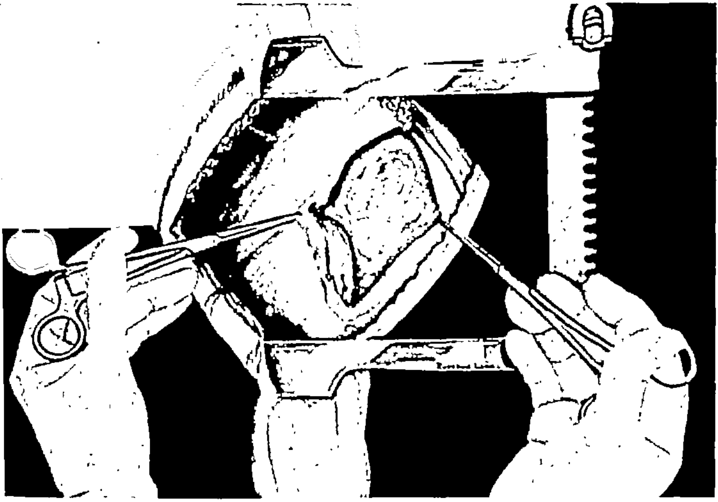


Fig. 1.—The first stage of the decortication. The membrane has been separated from the thoracic wall.

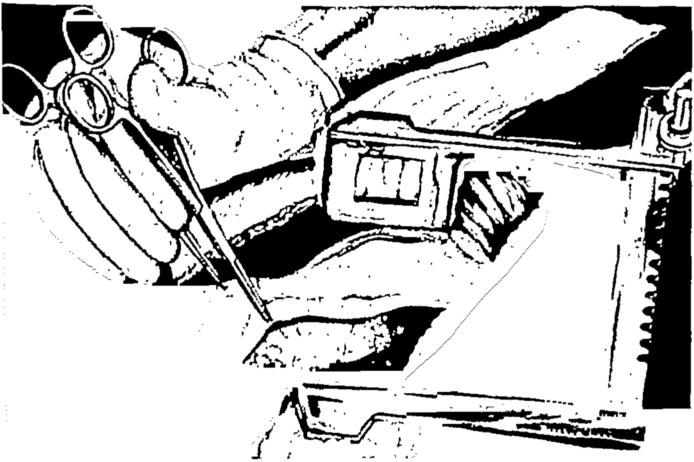


Fig. 2.—The separation is being continued onto the pulmonary surface. A plane of separation of the visceral membrane has been developed at the thickened margin which marks the junction of the parietal and visceral membranes.

Escape of air due to tears into the pulmonary tissue has occurred in all except the latest operation. The lacerations have varied from single areas a few millimeters in length to multiple areas several centimeters in length. Small rents are closed with interrupted No. 60 cotton sutures. Larger rents are sealed by suturing pieces of Fibrin Foam over the openings with interrupted fine cotton sutures (Fig. 3). This phase of technique is stressed because gross leakages may interfere with postoperative pulmonary expansion. In one case, failure to appreciate the importance of sealing pulmonary lacerations resulted in failure of the lung to remain expanded after operation. The surgical wound was reopened after nine days and a rent in the visceral pleura was discovered. This was sealed with Fibrin Foam and the patient went on to satisfactory recovery with complete expansion of the lung. The use of Fibrin Foam has been mentioned previously by Sanger.[10]

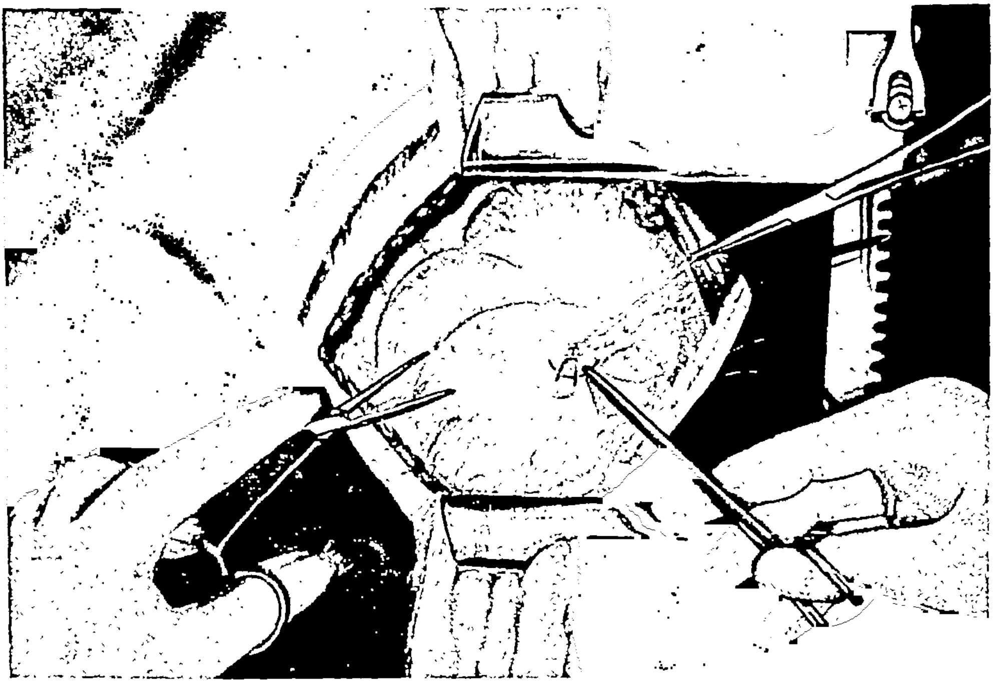
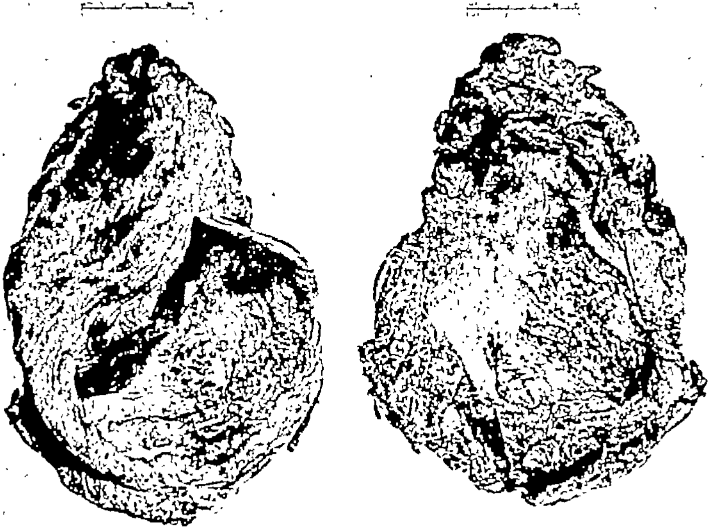


Fig. 3.—Method of sealing tears in the lung to prevent escape of air. A piece of Fibrin Foam is sutured over the opening with interrupted fine cotton sutures.

A preliminary report on the first five cases operated upon has been published elsewhere.[9] Of these, two cases were classified as undrained tuberculous empyema, two as threatened empyema, and one as tending toward obliteration of the pleural space with shifting of the mediastinum. Of the latest two cases, both are classified as threatened empyema. The underlying pulmonary tuberculosis varied in degree from moderate to far advanced. The ages of the patients ranged from 23 years to 37 years. The average time between definite fixation of the lung following pneumothorax and operation was six months, the shortest period by x-ray evidence being three months, and the longest nine months. All of the patients showed complete expansion of the lung within four days to four weeks. The postoperative convalescence was remarkably smooth considering the



A. *B.*

Fig. 4.—Intact membranous sac removed at operation. *A*, View of the costal surface of the opened sac. *B*, View of the visceral surface of the sac. The thickened ring encircling the visceral surface marks the junction of the visceral and parietal portions of the membrane.

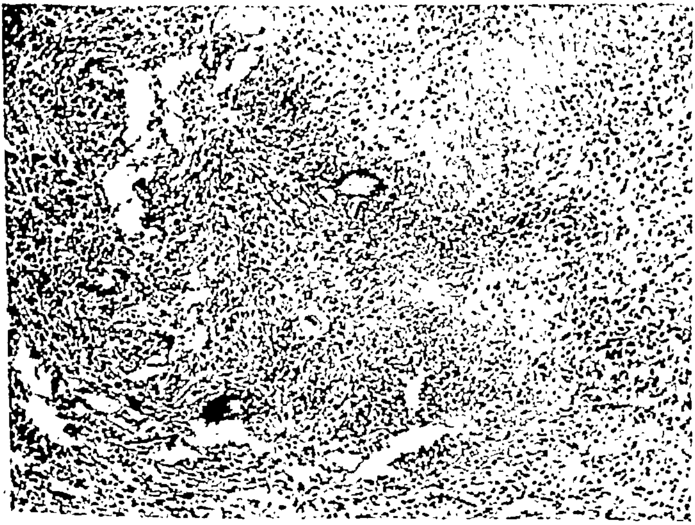


Fig. 5.—Photomicrograph of a section taken from the visceral surface of the membrane. Caseated tubercles with Langhans-type giant cells were observed in six of the seven membranes removed.

disease dealt with and the magnitude of the operation. Microscopic examination of sections of the membranes showed the presence of areas of caseation and epithelial tubercles with Langhans-type giant cells in all except the sixth case (Figs. 4 and 5).

The recent successes with decortication encourage one to believe that this method of treatment which restores the function of the lung and retains the integrity of the thoracic wall will largely replace the mutilating operations of the past. None of the patients included in this report has been observed longer than eight months, and further observations are necessary to evaluate the long term results. However, it can be stated that there has been no demonstrable spread of tuberculosis in the early period following surgery.

CASE REPORTS

CASE 6.—J. L., aged 32 years, was started on pneumothorax treatment elsewhere on Feb. 11, 1946, for treatment of a cavity in the right upper lobe. On admission to Birmingham Veterans Administration Hospital, March 30, 1946, x-ray examination showed the right lung contracted to about one-half normal size and a fluid level above the dome of the diaphragm. A twenty-four-hour sputum concentrate was positive for *Mycobacterium tuberculosis* in October, 1946.

A thick membrane had formed by November, 1947, and pneumothorax was discontinued. In March, 1948, it was estimated that the lung had been immobile for eight months.

The patient was started on streptomycin on April 1, 1948, preparatory to decortication. An episode of upper respiratory infection made it advisable to postpone surgery until April 26, 1948.

Operation was performed under nitrous oxide and ether endotracheal anesthesia. The patient was placed in position with the diseased side (right) uppermost. An incision was made in the fifth interspace from the midclavicular line to the paravertebral line, extending down to but not through the parietal pleural membrane. The rib spreader was inserted and the ribs were spread a distance of about 3 cm. The spreader was removed and the parietal membrane was separated from the thoracic wall for a distance of several centimeters on each side of the incision. The spreader was reinserted and the ribs were spread widely. A long incision was then made in the membrane and the fluid in the sac was evacuated. The separation of the parietal membrane was then continued in all directions. A single large vessel between the apical pleura and the thoracic wall was divided and ligated. The dissection was continued onto the visceral surface by developing a plane of separation at the thickened junction of parietal and visceral membranes. Removal of the membrane was accomplished almost entirely by blunt dissection. Several small areas of exposed parenchyma were pleuralized with No. 60 cotton sutures. One large uncovered area was sealed by suturing Fibrin Foam over the bubbling surface. The lung was folded on itself in several areas and these folds were released by dividing the restricting fibrous bands. Separation of the membrane from the diaphragm required sharp dissection in most areas. The diaphragm was perforated during the separation and the opening was sutured with interrupted No. 40 cotton sutures. The entire membrane was removed in one piece. The lung was inflated at intervals of twenty minutes or less after its exposure. Expansion was complete at the time of closure of the incision in the thoracic wall. Numerous bleeding points on the thoracic wall were coagulated electrically. One thousand cubic centimeters of blood were given during the operation.

Water-sealed thoracic catheter drains were placed in the third interspace anteriorly, and in the sixth interspace laterally. The thoracic wall was then closed with No. 40 cotton for the intercostal muscles and parietal pleura, continuous No. 0 catgut sutures for the extracostal muscles, and continuous cotton sutures for the skin. Before closing the thoracic wall, 200,000 units of penicillin and 1 Gm. of streptomycin in 10 c.c. of normal saline solution were instilled into the pleural cavity.

During the first twenty-four hours postoperatively, 1,000 c.c. of serosanguineous fluid were removed from the thorax through the intercostal catheters by means of continuous suction. Five hundred cubic centimeters were removed during the next twenty-four hours. The anterior catheter was removed on the fourth day and the lateral catheter was removed on the fifth day. The lung gradually expanded and filled the left hemothorax on the twenty-ninth day. The temperature reached a maximum of 102° F. on the second postoperative day and returned to normal on the sixth day (Fig. 6).

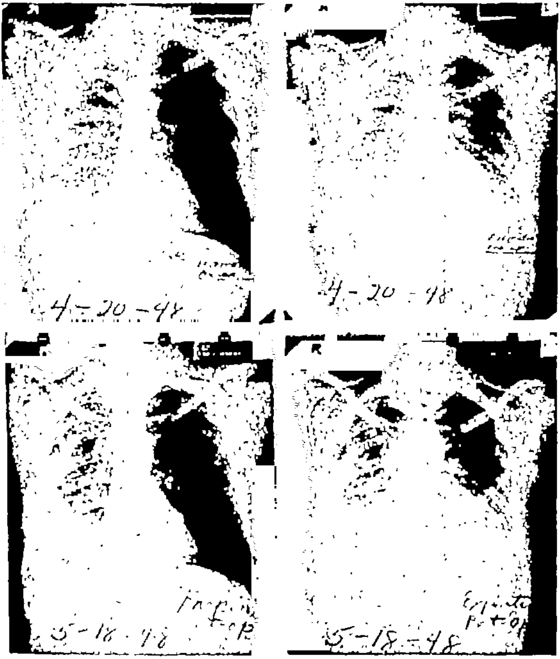


Fig. 6 (Case 6).—Upper left inhalation film and upper right exhalation film taken six days before decortication. Corresponding lower films taken twenty-two days after operation. Expansion was incomplete at the time these postoperative films were made, but was complete twenty-nine days after operation.

The capacity of the removed membranous sac was 700 c.c. The parietal membrane measured from 1 to 1.5 cm. in thickness. The visceral membrane was consistently about 2 mm. in thickness. The lining of the entire sac was moderately rough. Sections of the membrane examined microscopically showed fibrosis without evidence of specific tuberculous lesions.

Case 7.—J. M. was a man, 37 years of age. A diagnosis of tuberculosis with active disease in the left apical region was made in November, 1946. Cavitation was demonstrated several months later. The sputum was repeatedly positive for *Mycobacterium tuberculosis*.

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The recent successes with decortication encourage one to believe that this method of treatment which restores the function of the lung and retains the integrity of the thoracic wall will largely replace the mutilating operations of the past. None of the patients included in this report has been observed longer than eight months, and further observations are necessary to evaluate the long term results. However, it can be stated that there has been no demonstrable spread of tuberculosis in the early period following surgery.

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Five hundred cubic centimeters of serosanguineous fluid were removed by suction during the first twenty-four hours. The anterior tube was removed on the third day. X-ray films showed the lung to be completely expanded on the fourth postoperative day and the lateral tube was removed at that time. The temperature remained normal after the seventh day, and the patient has felt well since then. Thoracoplasty was added on May 20, twenty days after decortication. Streptomycin is being continued for the treatment of the tuberculous enteritis.

The sac contained several hundred cubic centimeters of thin, slightly turbid fluid. The parietal membrane varied in thickness from 5 mm. or less over the costal and diaphragmatic surfaces, to 1 cm. at the apex of the sac. The visceral layer was 2 to 3 mm. in thickness and was lined with irregular patches of fibrinofibrous tissue. Microscopic examination of sections of the membrane showed numerous areas of caseation and epithelioid tubercles with Langhans-type giant cells.

REFERENCES

1. Gurd, Frazer B.: J. THORACIC SURG. 16: 587, 1947.
2. Mulvihill, D. A.: Discussion of Gurd,[1] p. 597.
3. Woodruff, W.: J. THORACIC SURG. 7: 420, 1938.
4. Goorwitch, J.: American Rev. Tuberc. 47: 394, 1943.
5. Lam, C. R.: Arch. Surg. 56: 1, 1948.
6. O'Brien, E. J.: Discussion of Gurd,[1] p. 599.
7. Eggers, Carl: Discussion of Gurd,[1] p. 600.
8. Tuttle, W.: Discussion of Lam: Arch. Surg. 56: 12, 1948.
9. S. Clin. North America, Dec., 1948, p. 1591.
10. Sanger, P. W.: Surg., Gynec. & Obst. 82: 71, 1946.

(*See discussion on page 385.*)

PHYSIOLOGIC OBSERVATIONS CONCERNING DECORTICATION OF THE LUNG

George W. Wright, M.D., Saranac Lake, N. Y., Lester B. Yee, M.D., Sunmount, N. Y., Giles F. Filley, M.D., Saranac Lake, N. Y., and Allan Stranahan, M.D., Albany, N. Y. (by invitation)

THE feasibility and effectiveness of decortication as it relates to obliteration of an undesired pleural space has been demonstrated, but the effect of decortication upon pulmonary and circulatory function remains to be explored. In this paper, the data obtained from a study of three cases of decortication are presented and discussed, in part because the subject is timely, but also to indicate the need for more extensive studies of the physiologic aspect of pulmonary decortication. Of these three cases, one is representative of chronic traumatic hemothorax, another is an example of chronic tuberculous empyema, pneumothorax, and unexpandable lung, and the third is a case of spontaneous hemopneumothorax that persisted with a febrile reaction but sterile pleural fluid. The first two cases were studied before and after decortication, whereas the third was observed only after the operation.

Case 1.—Chronic traumatic hemothorax. A 22-year-old white man was admitted to the Veterans Administration Hospital at Sunmount, N. Y., on Dec. 8, 1947, with a history of having been stabbed a few hours previously, as evidenced by a puncture wound four inches to the right of the tenth dorsal spine. Roentgenograms at the time of admission revealed the presence of fluid in the lower third of the right hemithorax. A film on December 13 showed complete disappearance of the chest fluid but on December 17 (nine days after admission), fever began to develop and roentgenograms on that date showed a recurrence of the fluid in the right hemithorax. A specimen of the pleural fluid at this time was bloody but negative for bacteria by smear and culture. Chest fluid obtained at a later date did, however, contain a pure culture of *Staphylococcus aureus*. The patient was treated by intermittent removal of fluid from the chest and administration of penicillin. In spite of this treatment, the fever persisted, at times being as high as 102° F., and attempts to tap the chest became unproductive (Fig. 1, *A*). Decortication of the right lung was performed by Dr. Warriner Woodruff on Jan. 22, 1948 (forty-five days after the injury), the right hemithorax being entered after removing the fifth and a small portion of the fourth and sixth ribs. The pleural space was found to contain clotted and laked blood and there was a white, leathery peel about 5 mm. thick overlying the pleura. This peel was removed from the lung by blunt and sharp dissection and a fibrous layer was removed from the diaphragm. No attempt was made to remove the membrane from the parietal pleura. Under positive pressure, the lung was well expanded and closure made in the usual fashion with drain. Recovery was essentially uneventful. Fluoroscopy one month after decortication showed that the diaphragm and chest wall on the right moved in an almost normal manner (Fig. 1, *B* and *C*).

Case 2.—Chronic tuberculous empyema, pneumothorax, and unexpandable lung. A 39-yera-old white man was admitted to the Veterans Administration Hospital at Sunmount, N. Y., in the fall of 1942 with a diagnosis of extensive bilateral tuberculosis (Fig. 2, *A*).

From the Veterans Administration Hospital at Sunmount, N. Y., and the E. L. Trudeau Foundation, Saranac Lake, N. Y.

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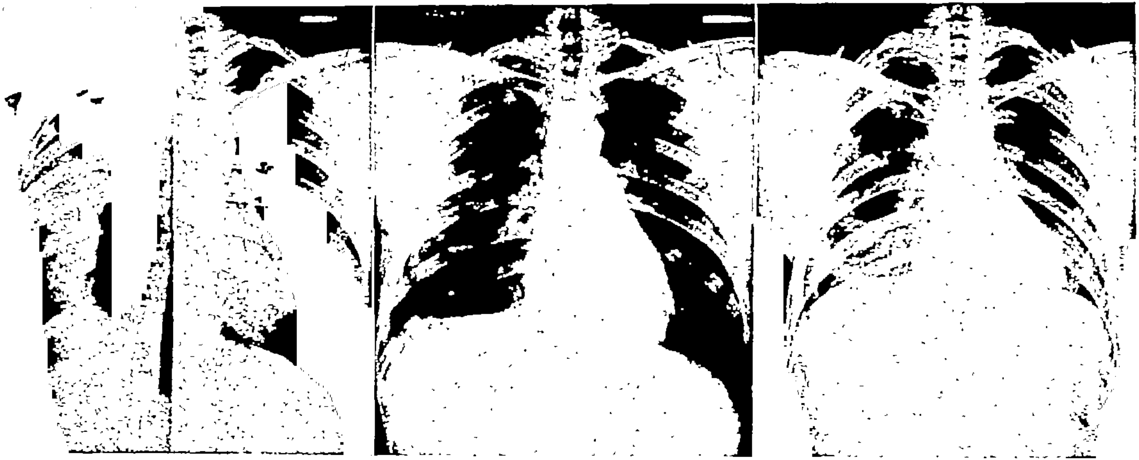


A. B. C.

Fig. 1 (Case 1).—Chronic traumatic hemothorax. *A*, Immediately before decortication; *B*, after decortication, full inspiration; *C*, after decortication, full expiration.

Left pneumothorax was begun in November, 1942, and was abandoned uneventfully in March, 1945. A right pneumothorax was begun in February, 1943. Empyema with tubercle bacilli in the pleural fluid was noted as early as February, 1944. The empyema persisted, the fluid being negative for all organisms except the tubercle bacillus. The lung could not be reexpanded beyond an estimated one-quarter of its volume in spite of the use of high negative intrapleural pressures which were associated with discomfort (Fig. 2, *B*). Bronchopleural fistula was not suspected or demonstrated at any time. On June 12, 1947, Dr. Edward Welles decorticated the right lung. The hemithorax was entered after removal of the fifth rib and the lung was found to be encased beneath a thick, leathery, yellowish-white fibrous covering, which when incised was found to be approximately 6 mm. thick. The peel was removed, in

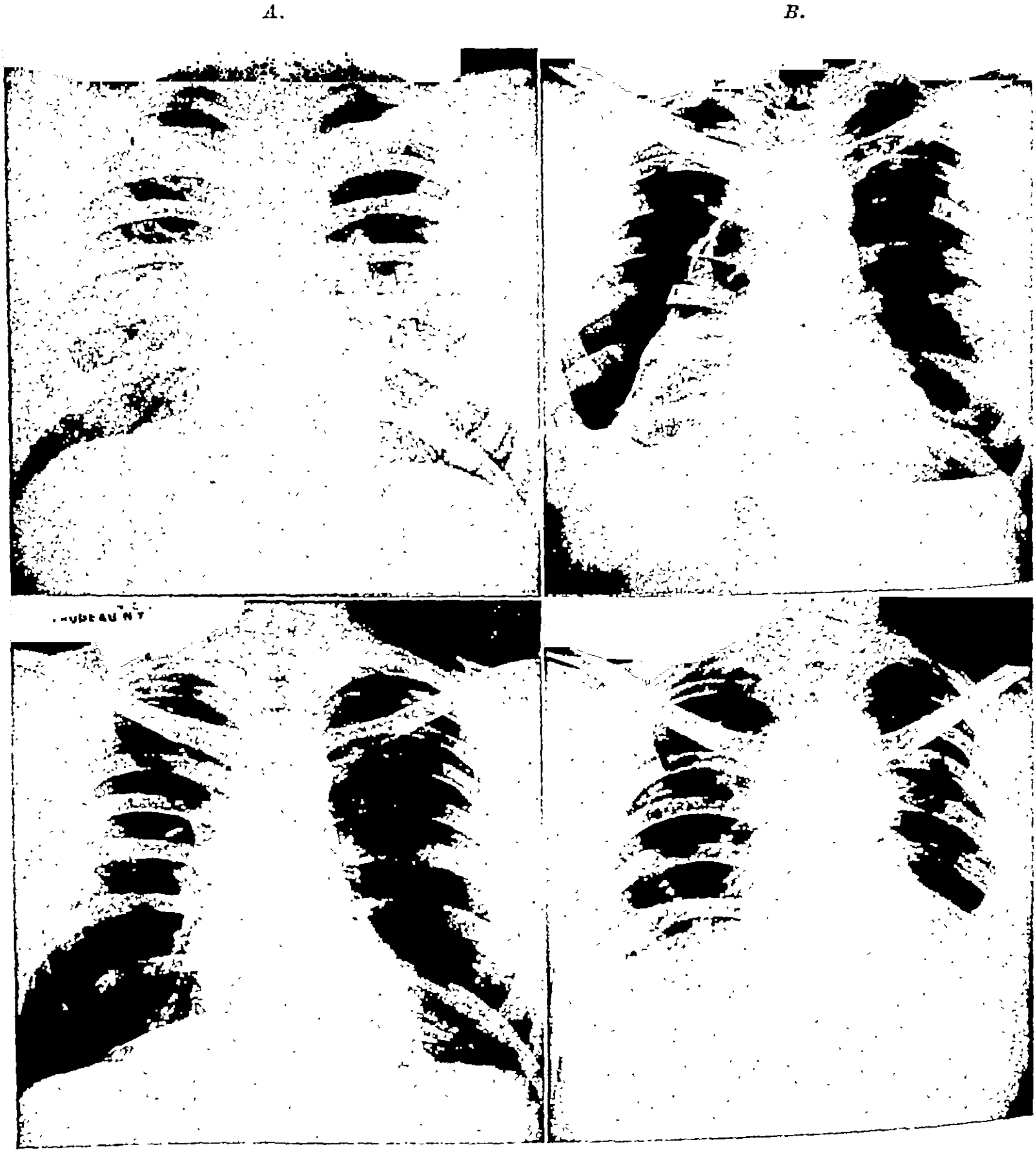
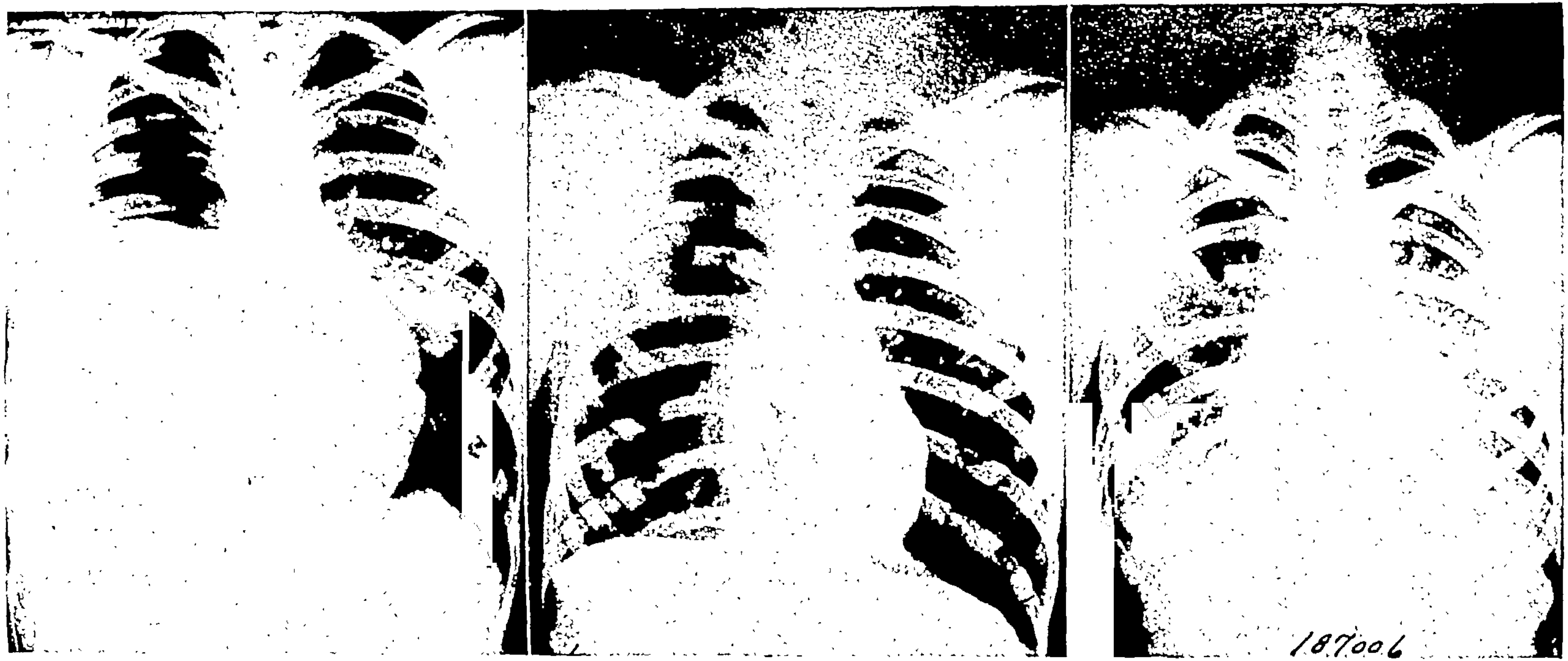


Fig. 2 (Case 2).—Chronic tuberculous empyema. *A*, Before pneumothorax was induced; *B*, immediately before decortication; *C*, after decortication, full inspiration; *D*, after decortication, full expiration.

some places by blunt dissection, but in others by sharp dissection, from the entire lung except for its diaphragmatic surface. The parietal pleura also was noted to be covered by a dense fibrous sheet which was not removed, nor was the membrane removed from the diaphragm. The right lung was completely re-expanded by positive pressure in spite of numerous areas of moderate air leakage from its surface. Prior to expansion, Dr. Welles palpated several tubercles in the compressed right upper lobe. The thorax was closed with a drain in the upper anterior and also the lower posterior aspect of the chest wall. Recovery though delayed was essentially uneventful. Complete re-expansion of the lung and obliteration of the space was finally obtained without further procedures (Fig. 2, *C* and *D*). Fluoroscopy shows that the right hemidiaphragm moves 1 cm. during quiet breathing and 5 cm. during full inspiration and expiration. The left hemidiaphragm moves 3 cm. during quiet breathing and 6 cm. during maximal breathing. Rib motion of the right is equal to one-half that of the left side. These observations are confirmed by a comparison of films taken on inspiration and expiration. The parenchyma of the right lung does not show normal filling and emptying as judged by changes in density. There is objective evidence of moderate trapping of air in the right lung.

CASE 3.—Spontaneous hemopneumothorax, complicated by empyema (?). A 21-year-old white man with no previous history of relevant illness, was suddenly seized with a sharp pain in his right chest while sawing wood. A few hours later he developed moderately severe dyspnea even at rest. Two days after this occurrence, he called a physician who strapped his chest after finding evidence of a hydrothorax, pneumothorax (?). He was admitted to the General Hospital in Saranac Lake on Feb. 15, 1948, at which time a roentgenogram revealed the presence of a hydropneumothorax (Fig. 3, *A*). The chest fluid was sampled and found to contain blood. The patient's clinical course in the hospital was characterized by high, variable fever from the time of admission until March 12, by which time the febrile reaction had subsided. Although no organisms were ever obtained from the pleural fluid, the reduction of fever occurring concomitant with the administration of penicillin strongly suggests that there was a bacterial infection of the pleural space. There was no history or evidence of bronchopleural fistula and the pleural space was not drained. The etiology of the hemopneumothorax is unknown. The patient had roentgenograms of the chest which were interpreted to be normal in February, 1947, and also in September, 1947. On March 13, 1948, Dr. Warriner Woodruff decorticated the right lung. The pleural space was entered after removal of the sixth rib and its contents were found to consist of approximately 2.0 L. of clotted blood. The lung was seen to be contracted down against the mediastinum and the pleural surface was covered with a smooth membrane, approximately 2 mm. thick. This covering was fairly solid but in places had the consistency of wet blotter paper. It was peeled from the lung with no difficulty, the operator commenting that it separated from the lung about as the peel separates from a tangerine. The oblique fissure was freed as was also, though to a lesser extent, the transverse fissure. The diaphragm was freed from the lung and chest wall and a considerable amount of shaggy material was removed from the diaphragm. The parietal pleura could not be freed without removal of underlying pleura, so it was not decorticated. The lung re-expanded perfectly under positive pressure and the pleura appeared in all places to be normal. There was no evidence of any parenchymal abnormality. The chest was closed and the lung expanded in the customary fashion. Convalescence was uneventful, the right lung completely filling the right hemithorax (Fig. 3, *B* and *C*). Fluoroscopy forty days after the operation shows that during quiet breathing, the right hemidiaphragm moves approximately half as well as the left, the motion being approximately 1 cm. on the right and 2 cm. on the left. During forced breathing, however, the right diaphragm moves in a more nearly normal fashion. Rib motion seems to be equal but somewhat restricted on both sides. The left lung appears to empty in a normal fashion but the right lung does not empty to the usual extent. This is confirmed by a comparison of inspiration-expiration films. Bronchoscopy performed forty-five days after the operation revealed an essentially normal tracheobronchial tree. The tracheal lumen was stated to be definitely small for a man of this size and age. Nothing was found to help explain the unexpected bronchospirometry data.



A. B. C.

Fig. 3 (Case 3).—Spontaneous hemopneumothorax. *A*, Immediately before decortication; *B*, after decortication, full inspiration; *C*, after decortication, full expiration.

METHODS

Maximum Breathing Capacity.—Maximum breathing capacity, hereafter referred to as MBC, was measured according to the method described by Hermannsen.[1] The subject hyperventilated voluntarily for thirty seconds through a high-velocity valve into a Douglas bag, the estimate being expressed in liters per minute. The predicted value was obtained by the use of a provisional regression formula[2] obtained in this laboratory from a statistical analysis of data gathered from a study of 250 normal healthy men. This formula is as follows: MBC — 197.5 – (1.36 × age). The standard deviation of the mean from which this formula is derived is 25 L., therefore the normal range can be expressed as a predicted figure ± 50 L. *Pulmonary Volumina:* the subdivisions are as follows: total volume = vital capacity plus residual air, vital capacity = complementary air plus reserve air, mid capacity = that volume of air in the lungs at mid position of the thorax or at the end of a natural or subconscious expiration, complementary air = maximum volume that can be inspired from the mid position, reserve air = maximum volume that can be expired from the mid position, residual air = mid capacity minus reserve air. The vital capacity was measured by a recording spirometer, the mid capacity by the method of Cournand and associates[3] modified to correct for the point at which the subject is turned into the open circuit. *Ventilation efficiency* was estimated by a method developed in this laboratory and as yet unpublished. It is based on the principle of recovering nitrogen from the lung while pure oxygen is breathed in an open circuit. A figure lower than 85 per cent is indicative of poor ventilation.* *Bronchospirometry* was carried out according to the method[4] utilizing an open circuit for measurements. Anesthesia was obtained by sparing use of 2 per cent Pontocaine in the pharynx and Forrestier's Solution in the larynx and trachea. *Arterial blood samples* were obtained at rest by means of a needle puncture of the brachial artery. Those samples taken during exercise were obtained by means of an indwelling arterial needle placed in the brachial artery. All exercise was performed on a motor-driven treadmill and blood samples and expired air were obtained simultaneously after at least four minutes of exercise. Blood carbon dioxide and oxygen were determined by the method of Van Slyke and Neill.[5] All figures in these data have been corrected for physically dissolved gases. Carbon dioxide and oxygen tensions were measured directly by the method of Riley and co-workers.[6] The gradient between arterial blood and alveolar air (A-A gradient) was obtained by subtracting the determined arterial blood oxygen tensions from the calculated alveolar air oxygen tensions according to the method of Riley and associates.[7] *Metabolic responses* during exercise were obtained on a motor-driven treadmill, samples of expired air being collected during the fifth and sixth minutes of exercise, except in exercise periods of shorter duration, when the expired air was collected in the terminal minute of the exercise period. Oxygen and carbon dioxide content of expired air was measured by analysis with the Haldane apparatus. Minute ventilation, oxygen consumption, and carbon dioxide output were calculated from the expired air data and expressed in terms of the terminal minute.

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*The term "ventilation" used in this connection refers to distribution and mixing of gases in the lungs.

DESCRIPTION AND DISCUSSION OF DATA

The extent to which the pleural changes of chronic traumatic hemothorax reduced the pulmonary volumina and limited the degree to which the right lung participates in the act of breathing is clearly demonstrated (Table I) by the lung volume and bronchospirometry data of the preoperation study of Case 1. The fact that the right lung took up proportionately less oxygen than it should have, on the basis of its participation in the volume of respired air (15 per cent as compared to 30 per cent) is noteworthy. Since the arterial hemoglobin was normally saturated (Table II), this disproportion indicates that pulmonary artery blood flow was diminished to a greater extent than was ventilation[*] in the right lung. This is a nice illustration of the *usual* adjustment made by the pulmonary artery system whenever its supporting lung tissue is reduced in volume or respiratory motion. Such a diminution of blood flow prevents the arterial hypoxia that would otherwise develop if venous blood were permitted to traverse the nonventilated segments of lungs. Although the mechanism of this arrangement is not clearly understood, it is un-

TABLE I

		CASE 1			CASE 2			CASE 3
		PREOPERATION	POSTOPERATION 34 DAYS	POSTOPERATION 240 DAYS	PREOPERATION	POSTOPERATION 180 DAYS	POSTOPERATION 330 DAYS	POSTOPERATION 40 DAYS
Maximum Breathing Capacity—								
Determined in liters/min.		68	112	130	74	70	73	116
Predicted in liters/min.		168*	168	168	145	145	145	169
Pulmonary Volumina, Recumbent—								
Total volume†		2.45	3.51	3.85	2.92	3.77	4.28	4.64
Vital capacity		1.94	2.61	2.94	1.84	2.32	2.82	3.30
Mid capacity		0.98	1.49	1.46	1.32	1.64	1.87	2.07
Reserve air		0.47	0.59	0.55	0.24	0.19	0.41	0.73
Residual air		0.51	0.90	0.91	1.08	1.45	1.46	1.34
Ventilation efficiency %					65	69	66	
Bronchospirometry—								
Minute volume:	right lung	30	36	48	27	32	35	20
	left lung	70	64	52	73	68	65	80
Oxygen intake:	right lung	15	33	45	18	25	25	19
	left lung	85	67	55	82	75	75	81
Carbon dioxide output:	right lung	20	34	48	15	22	27	10
	left lung	80	66	52	85	78	73	90
Vital capacity:	right lung	12	38	46	34	36	46	26
	left lung	88	62	54	66	64	54	74

*Normal range = ± 50 liters.

All volumes are wet gas at 37° C.

†Predicted normal total volume for Case 1 = 4.34 liters, Case 2 = 5.14 liters, Case 3 = 5.0 liters.

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[*] The term "ventilation" throughout this text is construed to indicate the quantitative aspect of moving air into and out of the lung except when clearly indicated to mean otherwise.

TABLE II

	CASE 1			CASE 2			CASE 3
	PREOPERATION	POSTOPERATION 34 DAYS	POSTOPERATION 240 DAYS	PREOPERATION	POSTOPERATION 180 DAYS	POSTOPERATION 330 DAYS	POSTOPERATION 40 DAYS
Blood Obtained During Rest—							
CO_2 content in vol.%			43.75	46.0	49.7		52.4
O_2 content in vol. %		19.75	19.35	17.70	18.16		17.62
O_2 capacity in vol. %		21.00	30.85	18.00	20.91		18.42
Hemoglobin saturation %		94	93	98	87		95.7
CO_2 tension in mm. Hg			37	47	31?		40
O_2 tension in mm. Hg			82	70	64		82
A-A gradient in mm. Hg			15	13	34		9
Blood Obtained During Exercise—							
Treadmill grade (%)	4				6	6	10
Treadmill speed (MPH)	3.5				2	2	3.5
O_2 consumption: c.c./min.	1100				1050	1015	1600
CO_2 content in vol. %					47.6	46.2	42.45
O_2 content in vol. %	19.15				17.86	18.62	17.66
O_2 capacity in vol. %	20.70				21.06	21.58	19.32
Hemoglobin saturation %	93				82.5	86.2	91.4
CO_2 tension in mm. Hg					36	42	37.5
O_2 tension in mm. Hg					56	58	78
A-A gradient in mm. Hg					42	30	24

doubtedly one of the important adaptive functions of the body. The limitation of the function of the right lung was clearly due to a combination of plombage and incasement of the lung and chest wall by a relatively nonexpansile membrane.

That the loss of lung volume, and more particularly the reduction of pulmonary mobility, interfered markedly with the maximum ability of the respiratory apparatus to respire air is shown (Table I) by the reduction of MBC. The significance of this severe diminution is best shown by the effect it had on the subject's response to exercise. The highest intensity of sustained work on the treadmill attained by this subject was that of a 4 per cent grade at 3.5 miles per hour during which a peak of 1,100 c.c. of oxygen consumption per minute was reached (Table III). The realization that this maximum intensity of work is approximately one-third that which should be attained by a normal man of this age strikingly indicates the severe general crippling that was caused by the chronic hemothorax. Intolerable dyspnea, preventing the subject from reaching a higher level of work intensity, developed at such a low intensity of work for two reasons. The breathing response to work was exaggerated quantitatively as indicated by the elevated O_2v index (Table III). The respiratory apparatus was thus called upon for a larger than customary performance at this level of work. Moreover, this unusual respiratory burden was given to a crippled apparatus capable of delivering only 50 per cent or less of its predicted normal capacity. In normal persons, respiratory activity intrudes upon the field of consciousness when the breathing load (minute volume) reaches about 30 per cent of the MBC and becomes very noticeable at about 50 per cent of the MBC. As indicated by the dyspnea index in Table III (0.59 = 59 per cent), the respiratory sensations arising from the

TABLE III

	CASE 1			CASE 2			CASE 3
	PREOPERATION	POSTOPERATION 34 DAYS	POSTOPERATION 240 DAYS	PREOPERATION	POSTOPERATION 180 DAYS	POSTOPERATION 330 DAYS	POSTOPERATION
Grade	4%	4%	4%	0	0	0	14%
Speed in miles per hour	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Duration in minutes	6	6	6	6	6	6	6
*Ventilation in liters/min.	40.0	42.8	36.4	33.5	24.8	23.6	58.1
O_2 consumption in c.c./min.	1100	1055	1150	1040	1035	935	2020
CO_2 output in c.c./min.	960	975	1005	875	825	735	2280
†O_2v index	0.59	40.6	31.7	32.4	24.0	25.2	28.8
‡Dyspnea index	36.4	0.38	0.28	0.45	0.39	0.32	0.46
Clinical dyspnea	++++	±	0	++++	++	±	++++

*Ventilation expressed wet at 37° C. ambient pressure. O_2 and CO_2 dry at 0° C. and 760 mm. Hg.

†O_2v index $= \dfrac{\text{ventilation in liters/min.}}{O_2 \text{ consumption in liters/min.}}$ (Normal = 25 ± 5)

‡Dyspnea index $= \dfrac{\text{ventilation in liters/min.}}{\text{maximum breathing capacity}}$.

crippled respiratory apparatus reached a point of intolerable discomfort at a load which a normal respiratory apparatus would carry comfortably for a long period. Exertional dyspnea developing at such a low intensity of work was, therefore, due primarily to the low breathing capacity of the crippled respiratory apparatus and, secondarily, though appreciably, to an exaggerated respiratory response to physical effort.

Removal of the pleural plombage and the limiting membrane of the right lung permitted a nearly perfect re-expansion of the lung as shown in the roentgenogram (Fig. 1, *B* and *C*). A comparison of the films made with the thorax in full inspiration and expiration shows that the mobility of the respiratory apparatus was also improved. Physiologic measurements made 34 and 240 days after decortication reveal a clearly demonstrated improvement of lung mobility and volume, so that at the last observation the subject's status compares favorably with that of a normal man, although not quite attaining the predicted normal figures. Two observations merit special comment. From the bronchospirometry data of Table I, it is apparent that oxygen intake of the right lung increased *pari passu* with the improvement of ventilation; moreover, the arterial hemoglobin is normally saturated as shown in Table II. (The authors regret not having made this particular study during exercise.) Apparently a normal relationship between ventilation and pulmonary artery circulation was re-established in the newly distended right lung.

The data of Table III indicate a marked improvement of exercise tolerance. The subject experienced no exertional dyspnea whatsoever at the same intensity of work that caused intolerable dyspnea prior to decortication. A large increase of MBC and a lowered breathing response during exercise resulting in a normal dyspnea index (Table III) explain this gratifying result. Since arterial hypoxia cannot be invoked as the cause of overbreathing (high O_2v) prior to decortication, and since removal of the peel, etc., was associated with a return to a definitely more normal breathing response (lowered O_2v), one is tempted to postulate that the exaggerated breathing response during exercise prior to decortication was a manifestation of an unusual drive of the respiratory center by impulses arising in the lung and pleura. A similar effect was noted in Case 2.

In contrast with Case 1, the data of Case 2 must be considered with due regard to the fact that both lungs are the site of extensive healed parenchymal tuberculosis, and that the left lung had been partially collapsed by pneumothorax for twenty-nine months (See Fig. 2, *A*). The preoperation data of this case is identical with that of the first, both as to description and interpretation, with two exceptions. The residual air constitutes slightly more than the normal per cent of total volume, and the ventilation efficiency (efficiency with which nitrogen is removed from the lungs during respiration of pure oxygen) is slightly impaired in Case 2. These observations suggest mild emphysema of the lungs. In adition, the right lung participates to a greater degree in respiration during forced breathing than during quiet breathing in Case 2, suggesting the limiting membrane over the lung in this case was more expansile than it was in Case 1. Other than these two features, the same comments can be made about the relationship of ventilation to pulmonary artery blood flow in the compressed lung and about the response to exercise in Case 2 as were made about Case 1.

The postoperation data of Case 2 are, however, distinctly different from those of Case 1. Observations were made at 180 and 330 days after decortication. The pulmonary volumina data (Table I) demonstrate an increase in volume of air-containing lung that is consistent with the evidences of re-expansion shown in the roentgenogram (Fig. 2, *C* and *D*). In spite of this, there was but little increase in the degree to which the right lung participates in the act of breathing or in the uptake of oxygen during quiet breathing as measured by bronchospirometry. Only during a vital-capacity breath could the right lung be made to show a participation in air movement consistent with the roentgenogram change. These observations indicate clearly that the re-expanded lung does not fill and empty as easily as does the left lung. Inspection of the right lung tracing during bronchospirometry confirms this in that the movement of air into and out of the right lung lagged behind that of the left. The same action can be visualized fluoroscopically, in that, during quiet breathing, the density changes in the right lung occur much more slowly than they do in the left. During rapid deep breathing, the density changes of the left lung are normal, whereas the right lung shows much less change of density during rapid deep breathing than it does during quiet breathing. These observations are interpreted as evidence that the right lung, although re-expanded, is ventilated very poorly and contributes little if any more to breathing now than it did prior to decortication. One cannot differentiate between airway obstruction and loss of lung distensibility and elasticity as the factors responsible for the poor ventilation of the right lung. Either or both mechanisms play a role.

Perhaps the most striking postdecortication change in Case 2 is the development of arterial hypoxia (Table II), which is slight at rest but becomes significantly more severe during exercise. The fact that considerable quantities of incompletely oxygenated blood now traverse the lung is even more clearly indicated by the abnormally large A-A gradient, whose upper limit in normal persons is certainly no more than 15 mm. Hg. Since, prior to re-expansion of the right lung, this condition was absent, it is logical to associate the new development with re-expansion of the lung. It is reasonable to postulate that pulmonary artery channels have been reopened by the re-expansion of previously collapsed and immobile tissue. Knowing that the re-expanded lung is poorly ventilated, one can adequately explain the hypoxia by assuming that a considerable portion of pulmonary artery blood is now traversing the poorly ventilated portions of lung and emerging incompletely oxygenated to mix with the normally oxygenated blood in the left side of the heart. A second explanation would be that the re-expanded alveoli, now recirculated with pulmonary artery blood, have developed changes in the barrier between the blood and alveolar air so that there is an impedence to the passage of gas across the alveolar membrane. It would appear virtually certain that one, or perhaps to some extent both, of these mechanisms has been set up by the operation. The mechanism mentioned earlier, whereby the proper relationship between alveolar circulation and ventilation is maintained, seems to have failed in this instance. In our experience, re-expansion of lung tissue after even a prolonged collapse by uncomplicated pneumothorax has not led to hypoxia. Perhaps in time there will be a readjustment with the disappearance of the hypoxia in this particular case.

Hypoxia of the degree met with in this case is not necessarily incompatible with comfort, etc. It is something of a surprise to note how little effect (Table III) the hypoxia has on the response to exercise in this particular subject as indicated by the normal O_2v index. When exercising at his maximum of tolerated intensity (data omitted from Table III), namely, at a grade of 4 per cent, speed of 3.5 miles per hour, and oxygen consumption of 1,445 c.c. per minute, the O_2v index is still only 24.0 liters. Studies during recent years have shown that there is a considerable individual variation in physiological responses to hypoxia.

In passing, it should be noted that during the interval between the second and third study, Case 2 was trained in and faithfully performed respiratory gymnastics designed to promote re-expansion and mobility of the lung. Perhaps some of the increase in the volume of the lung and in its mobility was the result of these exercises. Unfortunately, the gain in air movement, etc., was not accompanied by perfect ventilation of all segments of lung or restitution of a normal blood gas barrier.

Preoperation studies were not made in the third case but can, with little chance of error, be assumed to mimic the first case in all respects. The postoperation data was, however, entirely different from that which we had anticipated. The pulmonary volumina, maximum breathing capacity, and resting arterial blood studies are consistent with the expected end result and compare favorably with the postoperation results obtained in Case 1. The bronchospirometry data (Table I), however, are clearly at variance with the anticipated estimate. Because of this, the study was repeated with special attention to proving to our own satisfaction that the result was valid and technical errors were excluded. The result of the second measurement duplicated that of the first. We are unable to explain the very low per cent to which the right lung participates in the respiratory act. Although physical examination, fluoroscopy, and a comparison of roentgenograms taken at full inspiration and expiration (Fig. 3, *B* and *C*) do not indicate perfectly normal ventilation of the right lung, they do suggest that it participates more than was measured by bronchospirometry. We are somewhat reluctantly forced to recognize that the repeated bronchospirometric estimate is more likely to be correct than are the other observations mentioned above and are, therefore, faced with the at present unexplained disproportion of function between the right and left lungs. During exercise, the arterial blood hemoglobin was not oxygenated to an entirely normal extent and the A-A gradient was moderately increased. These observations indicate the same things as discussed in reference to Case 2 but on a scale of lesser magnitude. The unknown etiology, the brief interval of time between the operation and the postoperation studies, the history of a small hemithorax since childhood, plus the finding of a small trachea, etc., at bronchoscopy, all indicate that unrecognized factors may exist and caution must be exercised in drawing any conclusions from this case.

COMMENTS

The observations made of these three cases suggest the following comments. Plombage (either air or liquid) plus the immobilizing effect of a relatively nonelastic membrane overlying the pleural surface does seriously cripple the respiratory apparatus. This adverse effect influences not only the capacity of the person to exercise but also, as in the tuberculous, limits the use of collapse procedures for the contralateral lung. Surgical evacuation of the plombage and removal of the visceral peel will, as in Case 1, effect a restitution to virtually normal pulmonary and circulatory function in an as yet unknown number and type of cases. Re-expansion of lung tissue with obliteration of the pleural space is not always, as in Cases 2 and 3, followed by a recovery of normal pulmonary and circulatory function of the involved lung. It is actually possible, as in Case 2, for decortication to eventuate in an abnormal relationship between circulation and ventilation in the re-expanded lung tissue. The ultimate degree to which the re-expanded lung regains its normal physiological capacities depends in all probability upon the extent and nature of the histologic alteration that develops in the collapsed lung. Such alterations are related to the disease process in the lung prior to and during its collapse, to the development of the chronic empyema, etc., and probably also to the length of time the lung is collapsed. It is of interest that in none of these three cases was the parietal membrane peeled from the underlying pleura. From the data of Case 1, it would appear that this made no marked difference in the ultimate outcome. It should be remembered, however, that this membrane was present during a relatively short period. In

Case 2, the membrane had been present for a matter of years and in spite of its not being removed, there is evidence of some improvement in mobility of the underlying lung tissue. As to whether there would be better mobility now had the parietal membrane been stripped is a matter of conjecture. It is apparent from these studies that re-expansion and an improvement of lung mobility are of no avail if ventilation and circulation are not improved at the same time. These studies also indicate the need for detailed physiologic investigation of subjects before and after decortication. Analysis of the data thus obtained might in time enable one to predict the degree to which the re-expanded lung will recover physiologic integrity after decortication.

SUMMARY

1. Physiological studies of pulmonary function are reported in a case of chronic traumatic hemothorax, one of chronic tuberculous empyema complicating pneumothorax with an unexpandable lung, and another of chronic hemopneumothorax (empyema ?) of unknown etiology.
2. Postdecortication as compared to predecortication observations demonstrate the abolition of the crippling effect of plombage and immobilizing membrane in the case of chronic traumatic hemothorax.
3. Studies prior to and after decortication in the case of tuberculous empyema, etc., show that, although the lung was successfully re-expanded, pulmonary function was not improved but was in fact further impaired.
4. Postdecortication studies of the spontaneous hemopneumothorax case showed an unexpected lack of function in a perfectly re-expanded lung.
5. The significance of these divergent results following decortication is discussed.

REFERENCES

1. Hermannsen, J.: Untersuchungen ueber die maximale Ventilationsgroesse (Atemgrenzwert), Ztschr. f. d. ges. exper. Med. 90: 130, 1933.
2. Wright, G. W.: Unpublished Data.
3. Cournand, A., Baldwin, E. D., Darling, R. C., and Richards, D. W.: Studies on Intrapulmonary Mixture of Gases. IV. The Significance of the Pulmonary Emptying Rate and a Simplified Open Circuit Measurement of Residual Air, J. Clinical Investigation 20: 681, 1941.
4. Wright, G. W., and Woodruff, W. W.: Bronchospirography. Ventilation and Oxygen Absorption of Normal and Diseased Lungs During Nitrogen Respiration in the Opposite Lung, J. Thoracic Surg. 11: 278, 1942.
5. Van Slyke, D. D., and Neill, J. M.: The Determination of Gases in Blood and Other Solutions by Vacuum Extraction and Manometric Measurement, J. Biol. Chem. 61: 523, 1924.
6. Riley, R. L., Proemmel, D. D., Franke, R. E.: A Direct Method for Determination of Oxygen and Carbon Dioxide Tensions in Blood, J. Biol. Chem. 161: 621, 1945.
7. Riley, R. L., Lilienthal, J. L., Proemmel, D. D., and Franke, R. E.: On the Determination of the Physiologically Effective Pressures of Oxygen and Carbon Dioxide in Alveolar Air, Am. J. Physiol. 147: 191, 1946.

DISCUSSION ON "DECORTICATION IN PULMONARY TUBERCULOSIS INCLUDING STUDIES OF RESPIRATORY PHYSIOLOGY" BY DR. JOSEPH GORDON AND DR. EDWARD S. WELLES;* "DECORTICATION OF THE UNEXPANDED TUBERCULOUS LUNG FOLLOWING PNEUMOTHORAX" BY DR. JOSEPH A. WEINBERG AND DR. J. DWIGHT DAVIS;† AND "PHYSIOLOGIC OBSERVATIONS CONCERNING DECORTICATION OF THE LUNG" BY DR. GEORGE W. WRIGHT, DR. LESTER B. YEE, DR. GILES F. FILLEY, AND DR. ALLAN STRANAHAN

DR. MARK H. WILLIAMS, Binghampton, N. Y.—Those of you who had experience with this operation in military service will agree that the procedure in that group of cases was comparatively easy. For the most part the peel stripped rather readily, leaving a clean, normal-appearing visceral pleura. At times this could be done by finger dissection. In contrast, decortication in the group of cases under discussion here today is a considerably more formidable procedure. If the technique that was used in the war is followed there *are, in my experience, considerable bleeding and bubbling of air, and the operation is a* tedious and laborious one. By modifying the technique somewhat, the separation of the peel can be considerably facilitated.

(Slides.) This is intended to illustrate the situation found at operation in the average case of this kind. The lung is not completely collapsed and is adherent below to the diaphragm.

As the first step in decortication it is suggested that one enter the plane of the pleural symphysis. This opens rather readily, and the lung can be separated from the diaphragm, pericardium, and the chest wall by sharp or blunt dissection with only a moderate amount of bleeding. This dissection is continued until the lung is entirely freed. At this point, the anesthetist is asked to inflate the lung. It now inflates considerably and the peel actually appears to shrink somewhat. The lower border of the membrane is now elevated using rather strong tension with heavy clamps.

By the use of sharp and blunt dissection, the peel can be taken off with minimal injury to the lung and minimal bleeding. It comes off fairly readily and during this procedure the anesthetist applies steady pressure. The dissection continues until sufficient lung expansion is obtained to obliterate the pneumothorax space. Usually it is not necessary to remove all the peel in order to get sufficient expansion to fill the chest. Some of the membrane can be left in place over the upper lobe to insure permanent collapse of the area which was originally the site of cavitation.

DR. WILLIAM M. TUTTLE, Detroit.—I am much interested in this discussion because we have had a fair experience with decortication of the lung in tuberculosis. To date, our group has done this operation on forty-three patients. The captive lung was of six months' to sixteen years' duration. The operation was done for the following indications: seven patients were operated upon as an adjunct to lobectomy to allow re-expansion of the remaining lobes; twenty-three patients were operated upon for nonexpanded pneumothorax with fluid and approximately 50 per cent of those fluids were positive for tubercle bacilli; three operations were done in the presence of a dry space with long-continued pneumothorax; seven were done for an incased lung following a tuberculous pleuritis with effusion which had organized; and three were done for tuberculous empyema. Of the group, all expanded except four. One patient died as a result of reactivation of disease. In two the sputum became positive, the source was never found and they eventually became negative. One re-expanded and reopened a cavity in the re-expanded lung and that cavity with bed rest and with streptomycin eventually closed.

We postulated at the start of this work that after all there were two things to be desired: one was possibly to increase the function of the lung and make breathing easier; the other was to obliterate an open pleural space. I think the more important thing is probably the obliteration of the pleural space. After all, we know that individuals who have an unexpanded lung over many years sooner or later develop fluid and possibly empyema, and many must eventually have a thoracoplasty, in order to obliterate the space. I believe one might postulate that in many of these individuals the return of function may not be too great in the re-expanded lung. This is because we know that the lung which has been involved in a tuberculous process in many instances loses its function almost completely. In other words, the pulmonary membrane is destroyed and the ability of the lung to absorb and use oxygen is greatly diminished. Dr. Wright's figures bear that out. You will note that the volume in the re-expanded lungs was relatively good, but that the ability of the lung to use the oxygen inspired was poor. The findings of Dr. Wright fit in with what one might predict in many of these individuals whose disease had been extensive.

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*See page 337 for article by Gordon and Welles.

†See page 362 for article by Weinberg and Davis.

We have not removed the parietal pleura because in our experience in wartime we found that it was not necessary. If the visceral peel is removed and the lung is allowed to expand against the chest wall, then for some reason the parietal peel thins out and it is unnecessary to remove it. It is my feeling that to remove this, and it is a nice operation to get the whole thing off as a sac, increases the bleeding considerably, increases the operative time, and I believe it tends to complicate the situation.

We are pleased with the operation but not too overly optimistic about this, because you are not going to be able to decorticate every lung of all patients who have a tuberculous empyema. There will be some in whom the peel is so intimately attached to the visceral pleura that its removal will certainly be impossible. We have had that experience. There are other instances in which it may not be desirable to remove the peel at all, and a thoracoplasty should be done because of previous underlying disease.

I can see really little justification for combining thoracoplasty and decortication. We should make up our minds which operative procedure we want to employ. I agree fully with Dr. Weinberg that it is probably best to decorticate the lung, allow the lung to re-expand, see the status of the underlying disease and then if thoracoplasty is necessary it can be done. In our series we had to do a thoracoplasty in four instances in which the decortication itself as a primary procedure failed to allow expansion of the lung.

DR. D. H. WATERMAN, Knoxville, Tenn.—Our interest was first drawn to the problem of decortication in tuberculosis about three years ago when we had occasion to do a pneumonectomy on a patient who had developed a carcinoma in an unexpandable pneumothorax lung. The ease with which the peel stripped from the pleura, after a three-and-one-half-year pneumothorax complicated by pleural effusion, was so striking that further trial was felt warranted. We believe very strongly that this procedure will soon come into general use when satisfactory re-expansion of a pneumothorax fails to take place.

It has already been brought out that examination of the first x-ray films is of course very important in planning the surgical attack.

In a very limited experience, we feel that actually the procedure is an easier one, so far as stripping is concerned, in those cases that have an unexpandable lung without empyema than it is in hemothorax cases. Our experience in the latter group is limited too, however. Dr. Tuttle and others have mentioned the fairly appreciable number of pneumothoraces we see which do not fall into the empyema group, but which have a thickened peel over the surface of the lung preventing re-expansion. Here is a way to convert such poor pneumothorax results into good ones.

DR. W. W. BUCKINGHAM, Kansas City, Mo.—So far the papers and the discussers have failed to bring out the fact that the procedure can be a reversible one. In other words, we can use this to re-expand the lung or we can use it to collapse the lung further. We have done this operation in seven cases, in three of which cavities were developing underneath the incompressible lung. These three were all very well stuck at the base. By peeling away the top, as one gets around to the edge, as Dr. Weinberg states, further collapse of the lung can be brought down into the mediastinum; so you end up in those cases with a better selective pneumothorax than you had before. Two of these cases had conversion of sputum. It was not thought that resection was advisable in these cases as two of these patients had pneumothorax on the other side, and the other a contralateral thoracoplasty.

DR. D. A. MULVIHILL, New York.—We have been continuously interested in this since the wartime experience with decortication of hemothoraces. A case that I reported at Detroit two years ago was an application of the procedure to one of the problems we have in tuberculosis. The indications I spoke of at that time were somewhat different from those brought out today, in that I thought decortication might be applicable to obliteration of the dry pleural spaces resulting from nonexpansion of a postpneumothorax lung. I do not know whether it will be as applicable, as Dr. Tuttle brought out, to cases of frank tuberculous empyema, but it will have a very definite place, I think, in overcoming the symptoms of the dry, long-standing pneumothorax space. These patients with controlled disease want to be relieved of the necessity of refills after a period of years. They also want to be relieved of the dyspnea and the feeling of tightness they have, if they do not get their refills frequently enough, and we want to relieve them of the dangers of empyema.

(Slides.) I would like to show one case.

In a paper which will appear in the JOURNAL OF THORACIC SURGERY, I have stated that I have hesitated to employ this procedure in any tuberculous empyemas. However, with streptomycin, I feel it is sometimes possible to sterilize the space, and then proceed with decortication.

DR. ROBERT BLOCH, Chicago.—The group of papers just presented dealt essentially with complications resulting from artificial pneumothorax treatment of long duration. I could not help reflecting on the whole issue of that form of collapse therapy. The chief reflection is that artificial pneumothorax treatment may not deserve to be the universal therapy for tuberculosis that it has come to be considered in many quarters. Two or three decades ago the average duration of the treatment was about one year; often, only a few months. We have learned since then that for satisfactory results the duration of the treatment has to average a minimum of three years. This necessity has been the chief cause of complications such as we heard discussed this afternoon. It is comparatively easy to keep a patient at rest up to a year but very difficult, and often emotionally, socially, and economically impossible, to keep his activities under control for three years or more when he is asymptomatic and in good general condition.

Eight years ago Dr. William Adams, Dr. William B. Tucker, and I presented a paper at the joint meeting of this Association and the American Trudeau Society which we called "Standards and Criteria in Artificial Pneumothorax Treatment." At that time statistics gained from the world's literature on the late results of artificial pneumothorax showed roughly that one-third of the patients so treated were considered cured; one-third, uncured but living; one-third, dead. There is reason to assume that the figures have not changed since. This morning during discussions of extrapleural collapse methods several of the speakers remarked that there was hesitancy among surgeons to introduce foreign materials into the thorax for collapse purposes; as an internist I want to express my own hesitancy to introduce air into the pleural cavity regularly and over periods of years, without the strict indications which time does not permit to discuss now.

DR. WARRINER WOODRUFF, Saranac Lake, N. Y.—I wish to make two points. First, Dr. Wright has credited me with performing the operation on "J. S." While I am listed on the records as the operating surgeon, Dr. E. S. Welles and I worked together and the decortication was actually done by Dr. Welles.

My second point is one which has not been raised in this discussion but should be. It concerns the value of a decortication instead of a Schede operation in the obliteration of a residual empyema pocket when the ordinary thoracoplasty has not been successful. We know that in the presence of an old empyema even an extensive thoracoplasty may leave a residual space. In the past a Schede has been our next step; but if decortication can be done, it has many advantages. It is cleaner and the wound heals more promptly and requires less aftercare. Even though Dr. Wright has demonstrated in the patient with long-standing tuberculosis that there was considerable impairment of pulmonary function following decortication, I am not sure that the impairment is greater than would have been obtained by a Schede, as with the Schede the patient would have been left with a chest wall that would have remained flaccid for a long time.

DR. ROBERT KLOPSTOCK, Jamaica, N. Y.—I should like to make only a brief statement: The presence of any chronic and even uncomplicated pneumothorax seems to result in a peel-forming fibrous deposit upon both the visceral and the parietal pleura without involving the pleura proper. This peel causes, even in the most inconspicuous case, some degree of nonexpansion of the previously collapsed lung or areas of it and infolds in places the pulmonary parenchyma. This condition seems to be present in spite of satisfactory "x-ray appearance" of re-expansion and re-aeration of the lung. The infolding of pulmonary parenchyma may appear as parenchymal pathology on the skiagram. (Of course, nonexpansion due to pulmonary pathology is not considered in this particular problem.)

Performing resections for pulmonary tuberculosis, we explored a significant number of patients who had either a maintained pneumothorax at the time of the operation, some of only two or three months' duration, or a re-expanded lung following pneumothorax treatment of shorter or longer standing. Without exception we observed the noted "pneumothorax-peel" and had to perform a decortication in order both to develop the fissures and to secure complete re-expansion of the remaining pulmonary parenchyma. The thickness of the peel varied from a few millimeters to a filmy sheath; but even a filmy sheath was sufficient to cause at least infolding of pulmonary parenchyma and prevent full re-expansion of the remaining lobe. I am aware, of course, that all of you doing the same type of work had the same experience. I feel, however, that this observation concerning the consistency of formation of a "pneumothorax-peel" should be stated and added to the data on the natural history of the artificial pneumothorax.

DR. GORDON.—First of all, I should like to express Dr. Welles' regret at not being here; he sends greetings. I should like to thank the discussers for what they have said. It is exactly what we need when seeking a new approach to an old problem.

Regarding removal of the parietal peel, I should like to show slides of a case which suggest that it may not be necessary where there is a good underlying lung. Apparent complete resolution of the thickening peel has taken place as the lung returned to virtually normal function.

DR. WEINBERG.—I wish to thank the several discussants for their comments. Dr. Tuttle wonders why it is advantageous to remove the entire membrane in one piece. In condensing my paper for reading, it is possible that I have not dwelt on the advantages sufficiently. First, it has been found to be much easier to remove all of the visceral membrane if the parietal membrane is separated first and the dissection is continued on to the visceral surface. Second, if one does not remove all of the visceral membrane, the lung will not expand completely following decortication. Third, it is possible that retained portions of the diseased membrane would encourage the formation of sinuses in the thoracic wall. Fourth, the greatly thickened parietal membrane will limit the excursions of the thoracic wall and diaphragm at a time when this function is most needed to restore complete expansion of the lung. Dr. Gordon's observation that the retained parietal membrane tends to recede in the weeks following visceral decortication is encouraging for those who prefer to limit the procedure to the visceral surface, but the simplicity of the removal of the parietal membrane argues in favor of its resection instead of relying on its later resorption.

The question is raised, "Why release a lung by decortication and perform a thoracoplasty later? Why not limit the surgery to a thoracoplasty in the first place?" The purpose of decortication is not only to obliterate a pleural space, which is a potential or actual tuberculous empyema, but also to restore the function of the compressed lung. After decortication, if it is seen that thoracoplasty is indicated for pulmonary compression, this can be done in a selective, purposeful manner. One who has visited the autopsy room and has seen a grossly cavitated compressed lung under the thickened membrane of a tuberculous empyema must realize that the diseased lung is not benefited by the haphazard compression which nature imposes on it.

ALLERGY IN PULMONARY TUBERCULOSIS

WITH SPECIAL REFERENCE TO AUTOTUBERCULINIZATION

A. R. JUDD, M.D., HAMBURG, PA.

THE life history of a tuberculous infection in the human subject follows an intensely interesting and complex pattern, particularly if this pattern is not interfered with by "outside forces." This pattern is characteristic of few other infections and its complexity probably is not equaled or surpassed by other common, so-called, bacterial diseases. Seldom in other except fungus diseases is the response of allergy developed with the same as, or greater frequency and exactness than, in human tuberculosis.

Allergy as it relates to classical pulmonary tuberculosis occupies a fundamental position for it is the allergic response of the individual that determines the characteristics of pathologic processes occurring in patients developing the secondary or reinfection phase tuberculosis. There exists a profound and fundamental distinction between the reaction of the tissues in a healthy, uninfected individual and the one who has already been infected by the tubercle bacillus, and in whom living tubercle bacilli are, therefore, present. The fact of their being present and living is essential to the continued presence of this reaction but the presence of an active tuberculous disease, however, is neither implied nor necessary.

Robert Koch (1891), through his now classical animal experiments, recognized this distinction, that is to say, the distinction existing between the reaction of individuals infected and those not previously infected by the tubercle bacillus. In more recent years, however, further studies have revealed the presence of two distinct factors, both growing out of a primary tuberculous infection, in an individual not hitherto infected by the tubercle bacillus. These factors are, first, allergy, and second, immunity. Each, I believe, represents an entity (by itself) distinct, related but not wholly interdependent.[1, 2, 12] Both serve to determine the sequence of events in a patient reinfected by tubercle bacilli. By definition, immunity is the ability of the organism to resist the living bacilli themselves, while allergy is the sensitization of the organism to the products of the bacteria.

An individual becoming infected by the tubercle bacillus for the first time is said to have (received) the primary phase, or first infection, that phase of a tuberculous infection formerly recognized as childhood tuberculosis and so named because of the high frequency of this infection in children and young individuals. However, the primary phase infection is not confined to childhood but may occur at any stage in life of a person not previously so infected. The primary infection is usually benign, free from pronounced or noticeable clinical reaction. This generally passes unnoticed. Pathologically, during the first (primary) infection it is to be noted that the invading bacilli, on the whole, are not retained at the site of invasion but are transported by the lymph system

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From the State Sanatorium, Hamburg, Pa.

to the regional lymph nodes and these in turn tend to become enlarged, caseous, and may later become calcified. During the course of this infection and after a certain incubation period, a state of hypersensitivity (or allergy) to the products of the invading organism is developed. This incubation period usually occupies a period of eight weeks, but sometimes longer. Likewise, there is produced a certain but essentially unmeasurable degree of immunity. Both remain with the patient so long as living tubercle bacilli continue to be present within the organism, although significant clinical and morbid tissue activity may be absent.

In the event that this primarily infected individual should become infected again, the sequence of events is strikingly different due to the existence of an allergic state. The invading organisms on the whole are now retained at the site of inoculation. A local, acute, allergic inflammatory reaction takes place. This reaction is characterized by an outpouring of polymorphonuclear leucocytes and plasma cells, which reaction is further accompanied by local tissue necrosis.

Experimentation has shown that an identical reaction takes place if tuberculin or dead tubercle bacilli are injected into such a hypersensitized subject. This reaction depends upon the fact that an otherwise bland material, tuberculin, now acts as a powerful, irritating, and necrotizing agent, a response encountered only in an individual who has developed such a specific allergic response to the products of the tubercle bacillus. As a consequence thereof, clinical, or reinfection phase, tuberculosis assumes a position of profound importance in the realm of specialized therapeutics.

Underlying the whole phenomenon of allergy in tuberculosis is the question of the specificity of tuberculin in the production of a specific hypersensitiveness, or allergy, in man or animal. Numerous reports have been submitted and many controversial questions raised. Some writers, especially Moro and Keller,[10] claim that a hypersensitiveness to tuberculin has been produced in nontuberculous infants and animals by using conjugate antigens. On the other hand, there are writers who frankly dispute this claim, principally on the basis of a lack of the specificity of the hypersensitiveness thus produced. However, in the light of the more recent investigations (Chase, Lewis and Seibert, and others[1, 2, 8, 11, 13]) we may definitely conclude that tuberculin is a specific antigen and that antibodies to tuberculoproteins are produced. By virtue of these investigations and the consequent conclusions, there now exists little or no doubt of the validity of a positive reaction to the standard cutaneous tests using old tuberculin or the purified protein derivitive (P.P.D.) in determining the specific hypersensitivity of an individual previously infected with tuberculosis.

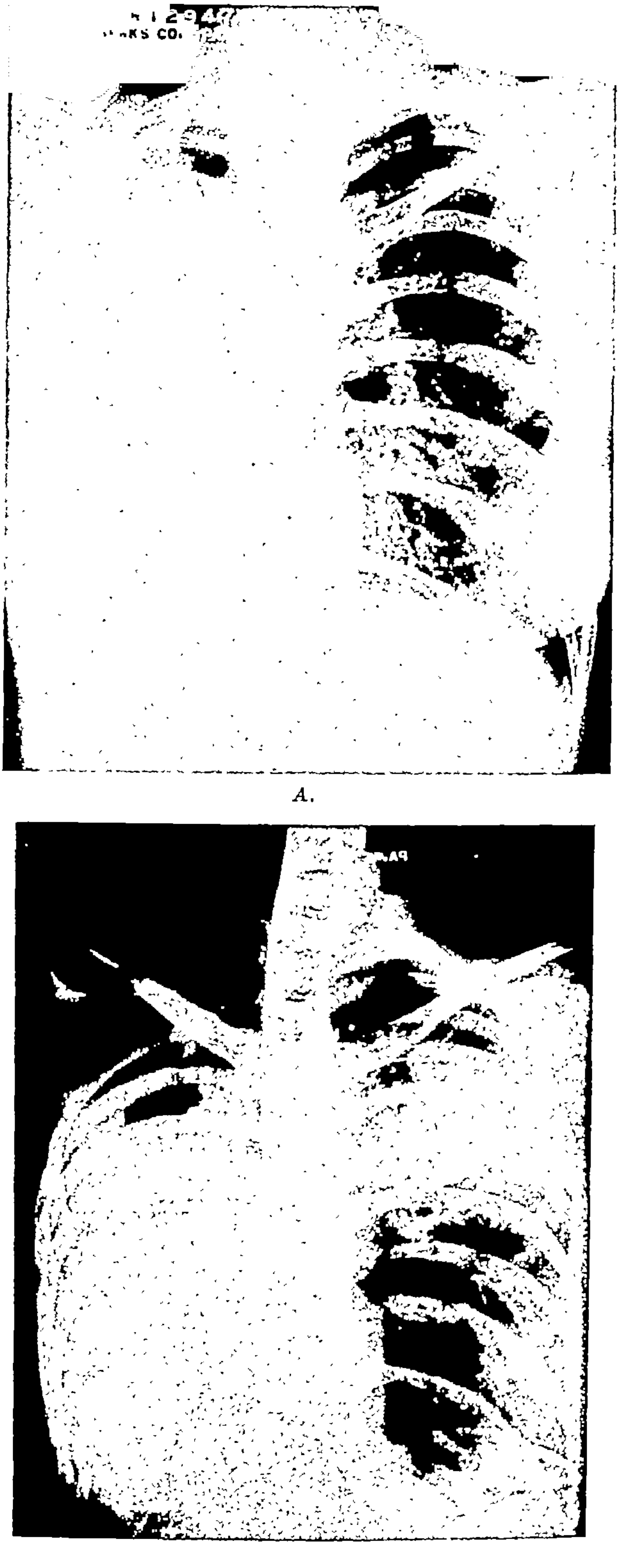
It should be emphasized that among phthisiologists the opinion is held that the duration of the allergic state is short (roughly fifteen months) unless living tubercle bacilli are constantly present in the body and therefore continually giving off tuberculin into the body system. Should the tubercle bacilli become extinct, a state of anergy would shortly ensue and thus the sequence of events characteristic of the reinfection phase tuberculosis would not constitute a danger until after a hypersensitivity to tuberculin should again have become established.

The problem of a loss of the allergic state and of true positive specific anergy still remains rather controversial. The loss of hypersensitiveness may be a permanent or temporary state. The permanent loss of a hypersensitiveness to tuberculin is a gradual process. It occurs in those cases where for some reason all living tubercle bacilli are eliminated from the body. This can, and does occur in rare instances following a primary phase infection but it is strongly doubted that this ever occurs following a reinfection phase tuberculosis. A temporary state of positive specific anergy, more appropriately described as a period of desensitization, or a period of suspended allergy, may be brought about by the gradual or sudden injection of adequate quantities of tuberculin into the lymph and vascular systems. This fact has been demonstrated repeatedly and conclusively in laboratory animals and is known to occur in the human being, especially consequent to the sudden collapse of a tuberculous lung as this takes place following the surgical decostalization of the chest wall, i.e., thoracoplasty. This phenomena has been described as autotuberculinization and has undoubtedly been witnessed by the majority of thoracic surgeons in certain of their patients following thoracoplasty even though it is highly probable that the condition observed was not recognized as such and that it may have been diagnosed as an "acute spread" (Fig. 1, *A* and *B*). According to Tuttle and his associates,[18] this reaction is one involving the union of antigen and antibody and, if severe enough, leads to desensitization of the host to the ordinary doses of tuberculin. Such patients show, by x-ray examination, evidence of an acute massive "focal inflammation" occurring in the region of existing tuberculous foci; this reaction may be of such severity as to endanger life and may in some instances bring about the death of the patient through the loss of a large volume of oxygen-absorbing surface or involvement of some other vital structure such as the meninges.

Within the past ten years a number of cases have been encountered in our clinic which, by and large, all presented a similar syndrome. However, because the earlier cases were not thoroughly studied, reference is being made only to those in which the characteristic syndrome appeared and in which the Mantoux test was found to be negative during the period of maximum physiologic reaction. All cases have occurred following thoracoplasty or extrapleural pneumonolysis.

Although the phenomenon of autotuberculinization has probably been encountered by all thoracic surgeons actively engaged in the surgery of tuberculosis, it is striking that so little reference has been made to it in the literature and that there are so many who doubt its occurrence.

The onset of the condition is associated with a high temperature elevation, which, however, is actively declining at the time the clinical symptoms and signs make their appearance. These symptoms and signs are characterized by varying degrees of apprehension, an undue blanching of the skin, followed by varying degrees of cyanosis, hyperpnea and dyspnea, and general prostration. The Mantoux test is negative and the roentgenogram shows an extensive "perifocal inflammation" around the foci of pre-existing tuberculous implantations. In the more severe cases, a memory lapse which may include a mild delirium has been noted during the most critical period even though the temperature was rapidly approaching a normal level at the time of this occurrence. The explanation we believe lies in the state of cerebral hypoxia in which the individual finds



A.

B.

Fig. 1.—C. K., a 40-year-old woman.

A, Preoperative roentgenogram of patient with giant right upper lobe cavity and dense pleural shadow resulting from old resolved tuberculous empyema.

B, Postoperative film of same patient illustrating typical "acute spread" to contralateral lung in contrast to the type of lesion seen immediately postoperatively in Figs. 2, *A*, *B*, *C*, *D*, *E*, *F*, and 3, *A*, *B*, *C*, *D*. Such lesions do not resolve spontaneously after a few weeks' bed rest. This patient progressed and died of fatal massive pulmonary hemorrhage.

himself. The prognosis in these cases is always grave and the earlier the onset (following operation, i.e., pulmonary collapse) the more severe the condition and the greater the danger to life.

Tuberculous infections in the presence of tuberculin allergy characteristically vary according to the intensity of the allergic state. This phenomenon may be demonstrated clearly by certain cutaneous manifestations of the infection. For example, lupus vulgaris exhibits all of the classical characteristics of a tuberculous infection of the skin and occurs in the presence of a high degree of tuberculin allergy. In contrast, other tuberculids occur in the presence of a low degree of hypersensitiveness and tubercle bacilli themselves are difficult to isolate or to find microscopically in these cases. However, in contrast to both of these types there is Boeck's sarcoid, etc., which, if we acknowledge a possible relationship to tuberculosis, occurs in the presence of no allergic reaction to tuberculin, i.e., a true state of tuberculin anergy. Tubercle bacilli cannot be demonstrated, yet the microscopic characteristics of the lesions are identical with the classically described tubercle except that associated tissue necrosis is absent. It is interesting that as a rule this disease is self limited, but occasionally such a case may progress, bacilli will be found, and the subsequent course follows that of any reinfection phase of tuberculosis. I know of no experimental data that adequately attempt to explain this phenomenon.

For a long while allergy and immunity in tuberculosis were considered together with no clear distinction being made between the two. However, it has been observed that while the invading bacilli were retained locally and killed in an allergic individual, this was not the result of allergy but the result of antibodies acting against living bacilli and, therefore, of immunity. It has been considered, until recently, that immunity was due to the allergy, or hypersensitiveness, to tuberculin. It is now admitted that such is not the case, yet it is still difficult to separate the two for any length of time. However, Rich and his associates[13, 14] do claim to have separated the two phenomena by desensitization with tuberculin without removing immunity. Yet, again, there are other opinions to the effect that the allergic inflammation may operate to enhance the immunity by hastening and concentrating the defensive forces at the site of infection. Therefore, they feel, allergy must be closely related to immunity.

While allergy, or hypersensitivity to tuberculin, is an undeniable and ever-present factor in clinical pulmonary tuberculosis and other manifestations of a tuberculous infection, one cannot escape the implication that an interrelationship may exist between the manifestation of allergy to tuberculin in the tuberculous patient, and the manifestations in the same patients to nontuberculous allergins, notably asthma. There is, however, a wide diversity of opinion on the subject. Some investigators believe that there is considerable interplay between the two; others are just as strongly of the opinion that asthma and pulmonary tuberculosis are mutually exclusive. Both opinions are challenged, and with equal integrity, by another group of workers,[19] who claim that the incidence of asthma among the tuberculous patients is no greater than among the population in general. From personal experience we could hazard the opinion that there seems to be considerable confusion resulting from mistaken diagnosis. In the first place, asthma, pollenosis, or other allergic manifestations do occur in tuberculous patients but apparently not out of proportion to their occurrence in the nontuberculous population. However, it is suggested that confusion apparently arises from the fact that symptoms of endobronchial disease, reduction of the size of the bronchial lumen, progressive intrapulmonary fibrosis with loss of vital capacity, emphysema, etc., are often not fully appreciated and, therefore, not infrequently misdiagnosed as "asthma." In 1944, Oatway and his colleagues[11] reported a series of interesting findings showing a strong possible relationship between endobronchial tuberculosis and hypersensitiveness to nontuberculous antigens. According to the opinion expressed by these investigators, we are to assume that the presence of a hypersensitiveness to nontuberculous allergins constitutes a predisposing factor to the development of tuberculous ulcerative endotracheobronchial lesions. To what extent such a hypersensitiveness may influence the ultimate prognosis of these tracheobronchial lesions, still remains uncertain.

It is possible that, after further clinical investigations, this report of Oatway and his associates may prove to be of considerable influence and significance, for up to the present time the exact nature of the underlying factors determining the occurrence and course of such tracheobronchial disease still remains vague or undetermined.

Irrespective of the influence of hypersensitiveness to nontuberculous allergins, it is difficult, at present, to subscribe to a theory which states that an extreme hypersensitiveness to tuberculin predisposes a patient to the development of "asthma" or "hay fever" of nontuberculous origin on the one hand, or to some specific manifestation of tuberculosis on the other. To arrive at such a conclusion one would, among other things, necessarily imply that certain predetermining inherited factors of susceptibility and immunity for both conditions would in some way be genetically linked, and no such relationship as yet has been demonstrated.

Finally, the relationship between the degree of intensity of the allergic reaction of hypersensitivity to tuberculin, and the course or progress of tuberculous disease in the individual, presents another quite controversial problem. To be sure, the type of disease is dependent upon the degree of allergy or anergy as we have already described, but it is a question whether the course of the disease is wholly dependent upon the degree of hypersensitivity. Is it not more likely that the manifested degree of hypersensitivity is dependent itself upon the course of the disease and the quantity of tuberculin discharged into the blood and lymph systems?

There are certain factors inseparably interrelated in any tuberculous infection:

1. The degree of racial susceptibility and immunity;
2. The resistance or "immunologic" state of the individual;
3. (a) The quantity, and (b) The virulence of organisms attacking the individual.

Depending upon the relative strength and interplay of these factors, the rate of progression of the disease will differ from one individual to another.

Similarly, it differs from one time to another in the same individual. Therefore, all types of tissue reaction are encountered side by side in the same lung or organ of the same subject. Urbach and Gottlieb (second edition) describe three histologic aspects of tuberculous hypersensitivity:

1. Progressive caseous type, which occurs when there is excess tuberculous antigen and only a small supply of antibodies;
2. The exudative form, caused by the presence of much tuberculous antigen and high antibody content;
3. Proliferative type, resulting from the reaction between a relatively small amount of antigen and a large supply of antibodies.

Assuming these histologic findings are the result of such varied antigen-antibody ratio relationships, it becomes less difficult to explain the clinical, roentgenologic, and pathologic findings in a wide variety of patients including both primary and reinfection types.

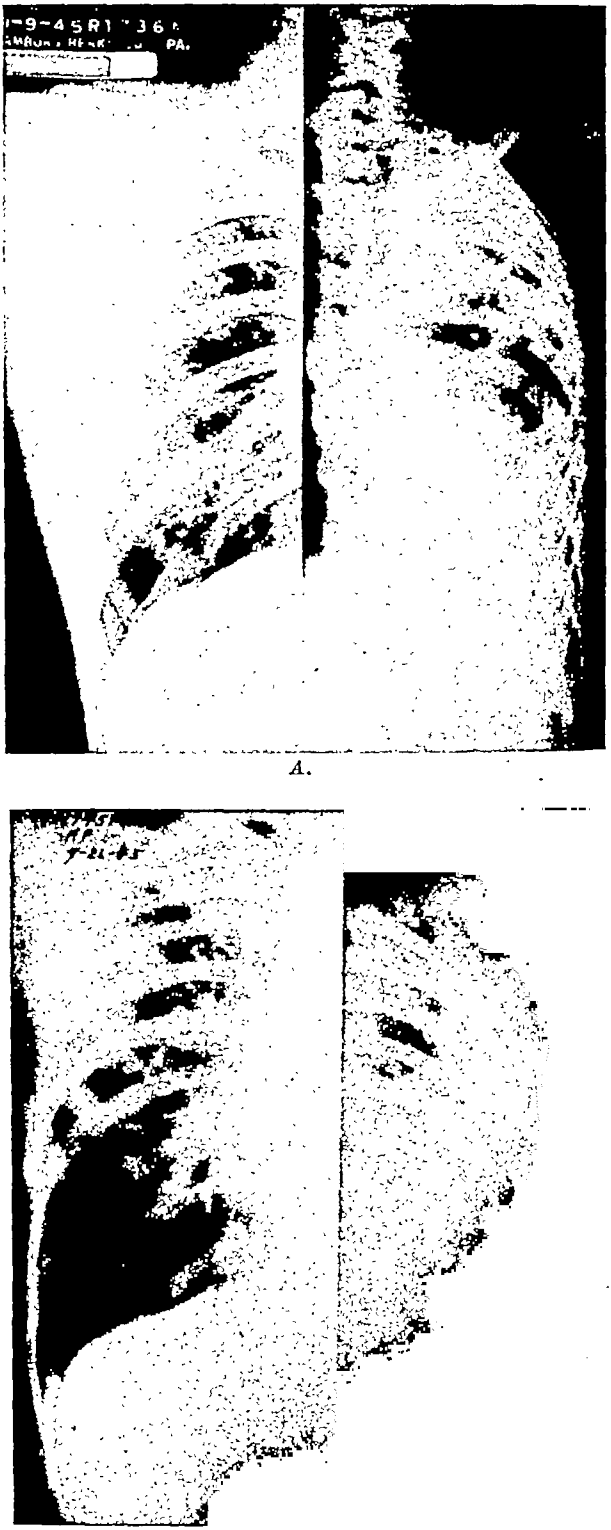
By way of summary, it is justifiable to conclude that:

1. As a result of a primary tuberculous infection, a state of allergy or hypersensitiveness to tuberculin is developed and that the cutaneous tuberculin tests correctly establish a patient's hypersensitiveness to the products of the tubercle bacilli.
2. There is a concomitant immunity established, but this immunity and the associated allergy are not inseparable.
3. The type of the disease depends upon the degree of allergy or lack of allergy (anergy) present.
4. A sudden collapse of a tuberculous lung may effect a sudden rise in the amount of tuberculin in the blood and lymph circulation. In consequence, there results a desensitization to tuberculin, i.e., autotuberculinization.
5. During the period of autotuberculinization a marked increase in perifocal inflammation around all tuberculous foci may so alter the physiologic state of the individual that death may ensue.
6. There are still many controversial points in so far as allergy and tuberculosis are related.

It is likely that these differences of opinion are the product of two factors, the lack of thorough understanding of the science of allergy on the part of the phthisiologists, on the one hand, and the lack of a thorough knowledge of tuberculosis on the part of the allergists, on the other. Much still remains to be learned about this most interesting and fundamentally important subject.

CASE REPORTS

CASE 1 (Fig. 2, *A*, *B*, *C*, *D*, *E*, *F*).—J. B., a 17-year-old Negro man, was admitted April 3, 1945, complaining of cough and expectoration. The patient stated that he was in good health until 1942, when a tonsillectomy was advised. The operation was planned for January, 1942, and a routine x-ray examination of the chest was performed, and an active pulmonary tuberculosis was discovered. He was eventually admitted to another sanatorium, May 7, 1942. An artificial pneumothorax instituted July 2, 1942, was discontinued as ineffectual in April, 1943. A left temporary phrenic nerve interruption was performed in September, 1943. During this period he developed a decided productive cough. The sputum was positive for acid-fast bacilli. Otherwise, he gained weight and experienced an uneventful course clinically.



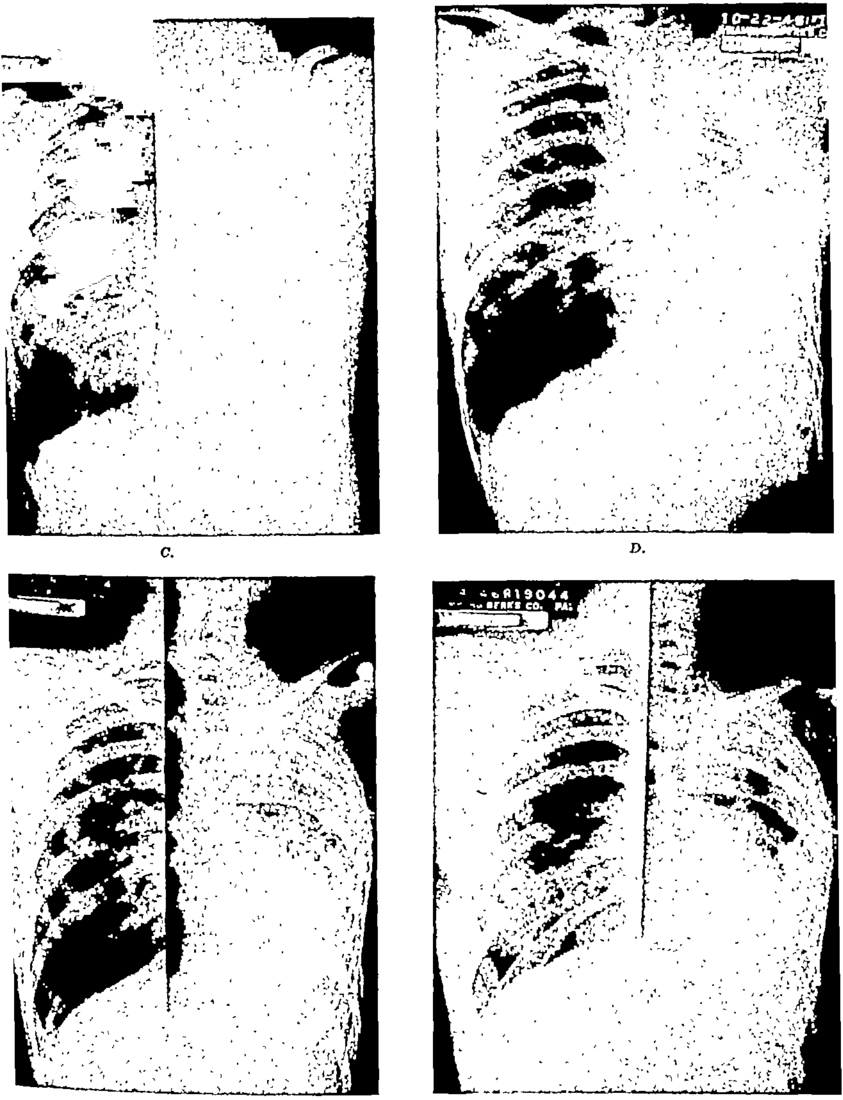
A.

B.

Fig. 2.—J. B., a 17-year-old Negro man.

A, Sept. 9, 1945. Preoperative roentgenogram showing extensive cavernous lesion in left. Note scattered nodular infiltrations in right lung (inactive for a period over one year).

B, Sept. 26, 1945. Postoperative film taken at time patient was becoming markedly dyspneic, with fever subsiding, Mantoux test negative, and patient moribund.



C. *D.*

E. *F.*

Fig. 2 (Cont'd).—*C*, Oct. 2, 1945. Film six days later. Patient showed rapid clinical improvement and roentgenogram revealed marked clearing of "infiltrations" noted in film of Sept. 26, 1945. *D*, Oct. 22, 1945. Patient fully recovered clinically. Further absorption of infiltrations noted especially at base, approximately one month since onset. Note clearing on left side. *E*, Nov. 19, 1945. Further absorption of process on both sides. Clinical condition excellent. Little change by comparison with film of Sept. 9, 1945. *F*, Roentgenogram approximately one year after acute process. Note open cavity on left side. Patient refused further thoracoplasty stages. Clinical condition excellent.

He was admitted to this sanatorium April 3, 1945. The past history, family history, and occupational history were noncontributory. The physical findings and x-ray examination here were compatible with a far-advanced pulmonary tuberculosis. He was accepted by the surgical service for thoracoplasty and the routine pre-operative studies were performed.

These included the following:

Essential laboratory findings: red blood cells 4,960,000 per c.mm., white blood cells 10,150 per c.mm., hemoglobin 92 per cent (Sahle). Blood type IV, coagulation time 3½ minutes (Lee and White), Rh factor positive, polymorphonuclear neutrophilic leucocytes 70 per cent, small lymphocytes 25 per cent, large lymphocytes 2 per cent, eosinophiles 1 per cent, basophiles 1 per cent, large monocytes 1 per cent, vital capacity 2 L., urine, no pathological findings, sedimentation rate 20 mm. in 60 minutes (Cutler), serologic examination for syphilis negative. Electrocardiogram and heart examination, "Normal cardiovascular system; no contraindication to thoracoplasty." Bronchoscopic examination, "No contraindication to thoracoplasty."

The first-stage thoracoplasty was performed Sept. 22, 1945. The usual technique was followed (two and one-half ribs resected) and the usual postoperative care carried out, including intravenous 5 per cent glucose and 500 c.c. whole blood. The patient experienced an uneventful course until suddenly, late in the evening, on Sept. 25, 1945, when he developed an acute respiratory emergency associated with the signs of shock, pallor, and sweating. The skin was cold and clammy, a feeling of tightness and "collapse" in the chest was complained of and was associated with a cough and frothy expectoration. Physical examination revealed coarse bubbling râles throughout all lung fields. He was considered to be most critically ill at this time. Supportive care, including intravenous fluids and oxygen therapy, and one transfusion, was administered. A Mantoux test was performed on Sept. 27, 1945, and showed no reaction. On September 29, considerable improvement was noted; this improvement continued uninterruptedly with complete recovery from the episode. A repeated Mantoux test was positive, plus 2, Oct. 22, 1945, first strength purified protein derivative.

The patient refused further thoracoplasty stages and was finally discharged against advice, May 9, 1947. At that time he was in excellent condition clinically. The sputum was still positive for acid-fast bacilli.

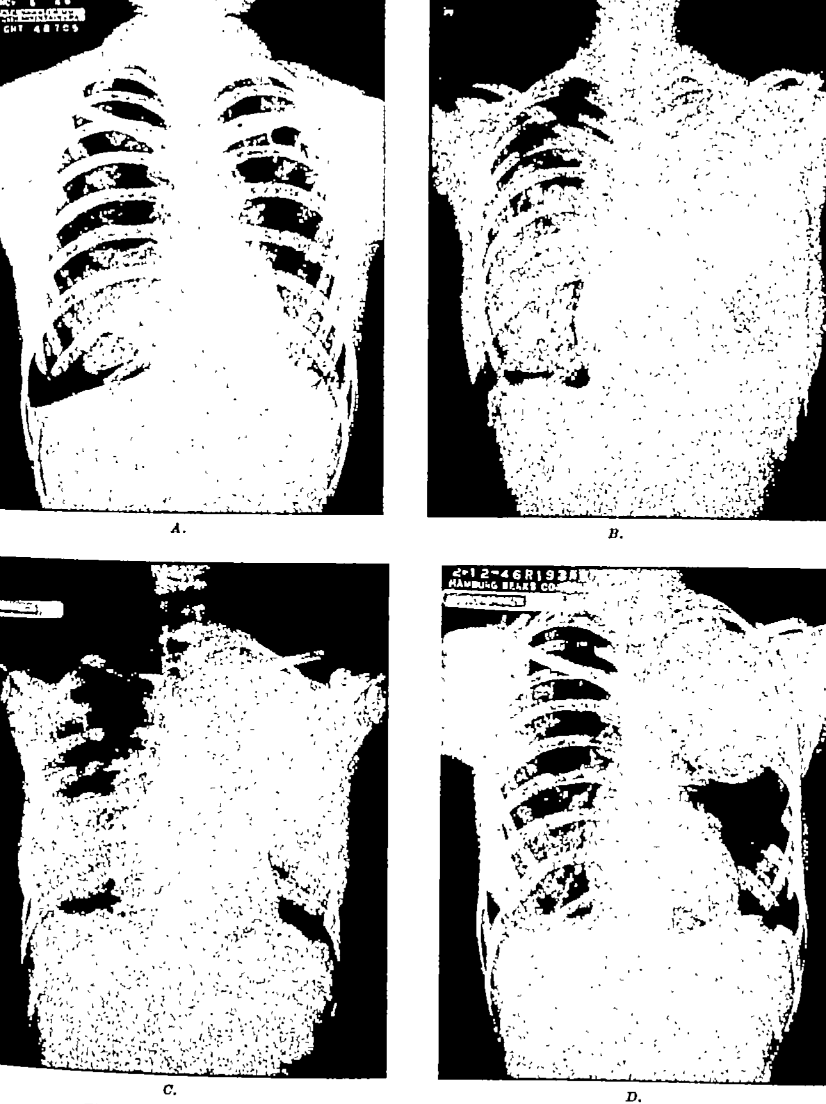
CASE 2 (Fig. 3, *A*, *B*, *C*, *D*).—M. B., a 23-year-old white woman patient, was admitted with a chief complaint of fatigue and loss of weight. She gave the following clinical history:

In January, 1943, her father and brother died of pulmonary tuberculosis. Because of this, x-ray examinations were made routinely and two small cavities were demonstrated in the left upper lobe. She had been completely asymptomatic up to this time.

Artificial pneumothorax was satisfactorily established and maintained for one year, when the lung was voluntarily re-expanded "because the cavities were healed," and the patient was permitted to return to work as a stenographer. She had worked for approximately one year when she experienced a pulmonary hemorrhage of moderate severity. The only other symptoms experienced up to the time of this hemoptysis were pain in the left chest and slight cough with essentially no expectoration. X-ray examination revealed larger cavities present in the left upper lobe. She was now admitted to a sanatorium where an attempt to re-establish a pneumothorax was unsuccessful. No other collapse therapy was attempted.

In February, 1945, she experienced a second hemorrhage. A left temporary phrenic nerve interruption was performed on Feb. 14, 1945, but this was not completely effectual in closing the cavities.

On April 8, 1945, a pneumoperitoneum was established. This, too, was not effectual. Routine serial roentgenograms now revealed an involvement of the right lung with small cavity formation. An artificial pneumothorax was successfully established on this side and the patient then was referred to this clinic for surgical collapse therapy to be directed against the cavities in the left lung.



A.

B.

C.

D.

Fig. 3.—M. B., a 28-year-old woman. *A*, Preoperative roentgenogram. Note cavity in left
lung, partially obscured by bony structures. Pleural symphysis precluded effectual pneumo-
thorax. Extrapleural advised because patient refused thoracoplasty being fearful of possibility
of resulting "thoracoplasty deformity." *B*, Postoperative roentgenogram, Nov. 29, 1946. Patient
was extremley dyspneic and definitely moribund. Both intrapleural and extrapleural pneumo-
thorax spaces were rapidly abandoned and the lungs re-expanded to obtain all possible avail-
able lung tissue. Mantoux test negative. *C*, Dec. 6, 1946. Marked improvement in the patient's
clinical status was accompanied by marked improvement in roentgenogram, as noted on this
film. *D*, Dec. 12, 1946. Roentgenogram approximately one month after onset of acute episode
showing tremendous improvement in pulmonary condition. Circumscribed density on left side
is due to some fluid still accumulating in extrapleural space. Lung was too well re-expanded,
so that re-establishment of pneumothorax space could not be accomplished.

Essential preoperative laboratory studies were as follows: red blood cells 4,820,000 per c.mm., white blood cells 10,650 per c.mm., hemoglobin 92 per cent (Sahle), polymorphonuclear neutrophilic leucocytes 66 per cent, small lymphocytes 33 per cent, eosinophiles 1 per cent.

Blood type: Landsteiner "O," Moss IV. Coagulation time, 5 minutes (Lee and White); serologic test for syphilis, negative; Rh factor, positive; urine, no unusual findings; sedimentation rate, 9 mm. in 60 minutes (Cutler); vital capacity, 1.3 L. (weight 87¾ lb.); electrocardiogram and heart examination, "no contraindication to major surgical operations."

Because of the patient's very extreme fear of a thoracoplasty, an extrapleural pneumothorax was performed Nov. 23, 1946. The technical phase of the procedure was exceedingly easy and quite uncomplicated. Postoperatively the patient's course was completely satisfactory until late in the afternoon on November 23, when she developed a moderate apathy and the peculiar pale appearance which we have come to associate with the type of condition we consider to be autotuberculinization. A Mantoux test was performed, which, after twenty-four, forty-eight, and seventy-two hours, showed no reaction of any kind.

On Nov. 29, 1946, the patient had become extremely dyspneic, agitated, prostrated, and cyanotic. She was placed in an oxygen tent. The course thereafter, was progressively downhill. Intravenous fluids and transfusions were administered. Respiration became progressively more "choppy" and labored. She was frankly comatose and moribund for three days. On December 1, near midnight, a very slight improvement was noted. This was more evident the following morning. Favorable progress, thereafter, was satisfactory and rapid. She was allowed out of the oxygen tent at intervals on December 5, and finally was removed from the tent on December 6.

This patient has essentially no memory of the events occurring during this period. By necessity the right lung was re-expanded, as was the left (extrapleural). The Mantoux tests were negative on Nov. 26, Dec. 2, and Dec. 7, 1946, and positive, plus 1, on Dec. 27, 1946.

We feel justified in concluding that the Mantoux reaction was positive prior to the operation. The patient's course has been satisfactory since that time and she has now successfully undergone a second-stage, five-rib, left thoracoplasty. The ultimate prognosis appears good for sputum conversion and complete recovery.

CASE 3.—B. S., a 29-year-old white woman, was admitted April 21, 1943, with a chief complaint of cough and expectoration. The present illness dates back to February, 1943, when the patient developed a "cold." This, she states, was associated with fatigability, cough, expectoration, and a "sore throat" so severe that swallowing was quite difficult. She consulted an otolaryngologist who, after examination, ordered a roentgenogram. A diagnosis of pulmonary and laryngeal tuberculosis was made. The patient was then admitted to the sanatorium. Except for pain in the left chest in 1938, the past and family histories were noncontributory.

Examination of the larynx showed extensive destruction, ulceration, and distortion of the laryngeal structures by fibrous contraction. The examination of the chest was suggestive of, and compatible with, an extensive pulmonary tuberculosis involving the right lung.

X-ray studies confirmed the diagnosis which was substantiated by the finding of acid-fast bacilli in the sputum.

The preoperative laboratory findings were essentially normal. The sputum was positive for acid-fast bacilli (intermittent); urine, no unusual findings; electrocardiogram and heart examination, "No contraindication to major surgical operations."

The patient's course in the sanatorium was as follows: In addition to the usual sanatorium regimen, she underwent the following collapse therapy procedures: right artificial pneumothorax, May 31, 1943, unsuccessful; left phrenic "crush," Aug. 10, 1944, unsuccessful; left phrenic "crush," June 7, 1945; first stage right thoracoplasty, April 6, 1946; second stage right thoracoplasty, May 11, 1946; third stage right thoracoplasty, June 15, 1946.

The patient's sputum then converted except for an occasional positive sputum. Because of the intermittent positive sputum a revision thoracoplasty was decided upon and performed following a technique with slight modification, as described in another communication.[5]

This operation was performed March 15, 1947. The postoperative convalescence was quite uneventful until late in the evening of March 19, when she progressively developed the characteristic symptoms of dyspnea, pallor, cyanosis, prostration, and modified delirium. She was placed in an oxygen tent and given supportive treatment which included intravenous fluids and transfusions. Mantoux tests were performed on March 21, March 27, and April 18, 1947. The last was positive (plus 1) while those of March 21 and March 27 were negative.

On March 28, 1947, an antihistamine substance, Benadryl, was administered and an immediate profound improvement was noted in the patient's condition. Whether this medication contributed anything to the patient's recovery, which was already progressing satisfactorily, cannot be claimed. It was, however, a rather unexpected observation. The oxygen tent was removed on March 30, and since that time the patient has progressed quite uneventfully.

CASE 4.—C. K., a 40-year-old white man, was admitted Aug. 23, 1945, complaining of excessive cough and expectoration. He stated that he was in excellent health until August, 1944, when, as a result of an examination of the chest following an accident, pulmonary tuberculosis was discovered. He was admitted to another sanatorium soon thereafter, where an x-ray and sputum examination confirmed this provisional diagnosis. In December, 1944, a right pneumothorax was established. This was followed by an improvement in weight, a reduction in cough and expectoration, and a bettering of the patient's general clinical well-being.

The patient later admitted that he had had a cough for several years prior to this injury, had noted a 15-pound weight loss, had had pleurisy in 1928, and had expectorated blood in August, 1944. The past, family, and occupational histories were noncontributory.

He was admitted to this sanatorium Aug. 23, 1945. The right pneumothorax was maintained. It was complicated by a pleural effusion which was aspirated as indicated. This was necessitated only at irregular intervals as fluids accumulated quite slowly. Attempts to collapse the right lung effectually by pneumothorax were unsuccessful, and the complicating effusion unfortunately showed progress toward empyema formation. Repeated thoracentesis, re-expansion of the lung, and a thoracoplasty were then advised.

The first stage was performed Oct. 27, 1945. The preoperative studies were essentially normal and revealed no contraindication to thoracoplasty. Electrocardiogram and heart examination showed normal cardiovascular system; bronchoscopic examination showed no contraindication to thoracoplasty.

Surgical Course.—The first stage thoracoplasty was performed Oct. 27, 1945. The postoperative course was quite usual and uneventful until the sixth postoperative day when the patient complained of dyspnea, appeared slightly cyanotic, was quite apprehensive, pale, and somewhat confused, and was definitely in respiratory physiologic distress. Oxygen and intravenous fluids (5 per cent glucose and normal saline) were administered. A Mantoux test performed at this time showed no reaction (purified protein derivative first and second strength). A positive reaction was not obtained until Dec. 2, 1945. The third day of the episode was the most severe and recovery was doubted. The patient was considered moribund but, following the third day, recovery was unusually rapid. This favorable progress continued and the patient was allowed out of bed in preparation for the second stage thoracoplasty. However, he experienced pulmonary hemorrhage from the right (thoracoplasty) side, and a consequent acute dissemination to the left lung. A pneumothorax was initiated successfully. The pneumothorax was maintained but this unfortunate sequence of events so delayed the institution of further thoracoplasty stages that war conditions caused a further temporary curtailment of the surgical program. As a result, the patient experienced a second pulmonary hemorrhage, the results of which were severe and progressive, and he died Aug. 31, 1946.

Remarks.—A complete serial x-ray series on this case was interfered with by the acute posthemoptysis dissemination to the left lung. However, the clinical course, the general reaction of this patient, and the presence of a negative Mantoux reaction and the available roentgenograms permit us to conclude that this case represents a bona fide example of autotuberculinization and we, therefore, feel justified in presenting it as such.

CASE 5.—F. A., a 24-year-old white woman patient, was admitted to this service March 13, 1943, with a chief complaint of cough and expectoration. She stated that she had been perfectly well until October, 1939. At this time she had experienced cough, expectoration, loss of weight, slight dyspnea, pain in the chest, and occasional frank hemoptysis.

She was admitted to a sanatorium Dec. 19, 1939, where, in addition to the routine sanatorium regimen, she received: right artificial pneumothorax, January, 1940; left artificial pneumothorax, July, 1941 (ineffectual); and left phrenic nerve interruption (temporary), Aug. 31. 1941. The right artificial pneumothorax was continued successfully. The patient was admitted to the surgical service for left thoracoplasty, March 13, 1943. The first stage was performed May 11, 1943. The second stage was performed June 17, 1943. A delay of two weeks beyond the usual three-week interval was necessitated because of a mild "reaction" postoperatively.

The physical examination and roentgenograms were compatible with a pneumothorax on the right side and a giant cavity and extensive infiltrations in the left lung.

The essential preoperative laboratory findings were as follows: red blood cells 4,610,000, white blood cells 19,650, hemoglobin 75 per cent (Sahle). Differential: polymorphonuclear neutrophilic leucocytes, 65 per cent; small lymphocytes, 22 per cent; eosinophiles, 6 per cent; basophiles, 1 per cent; transitional, 1 per cent; monocytes, 5 per cent. Sputum, positive for acid-fast bacilli (smear and concentrate); sedimentation rate, 32 mm. in 60 minutes (Cutler); vital capacity (with pneumothorax on right side), 1 L. (weight 106½ lb.); coagulation time, 3 minutes; serologic test, negative for syphilis; electrocardiogram and cardioexamination demonstrated, "no contraindication to major surgical operations."

Mantoux test, June 18, 1943, was negative. The patient died just after a forty-eight-hour observation of this one test had been made.

The first-stage thoracoplasty was performed May 11, 1943. Following this the patient experienced a period of markedly lowered clinical well-being, some dyspnea, and a moderate degree of prostration. Other than the usual supportive measures, including intravenous fluids, the only additional procedure necessary was the removal of all air from the pneumothorax side (right). The patient made a rather rapid recovery and she was considered a fair risk when the second stage was performed, June 17, 1943. Following this stage the patient returned from the operating room in good condition. Whole blood (500 c.c.) and intravenous fluids (5 per cent glucose) were administered with no immediate eventful occurrence. However, that night, after 11:00 P.M., the temperature rose very rapidly until it reached 101.8° F. the following morning at 8:00 A.M. At this time the patient did not show any unusual findings. However, by 2:00 P.M. on June 18, marked cyanosis, preceded by a decided pallor and anxiety, developed. This was then rapidly followed by an increasing dyspnea, prostration, and agitation. The temperature remained elevated and all other symptoms and signs progressed. The following day, June 19, they became extreme. Removal of all air to re-expand the collapsed lung, nasal oxygen and oxygen tent, transfusions, etc., were all administered without avail.

The patient died June 19, at 9:40 P.M.

Unfortunately, a post-mortem was not granted.

This has not been proved to be a case of undeniable autotuberculinization but the symptoms, signs, and clinical course were so typical that it is included among those reported, of course, with reservations.

DISCUSSION

Autotuberculinization presents a profound problem, for, at present, there appears to be no way by which the disturbing phase of the phenomenon can be predicted preoperatively. Although two cases are not reported herein because of incomplete data, there is almost conclusive evidence that two of our patients died as a result of overwhelming autotuberculinization wherein not only the lungs themselves were severely affected, but where the most predominant symptoms were meningeal and cerebral. We felt that in each of these cases, had the cerebral and meningeal symptoms (tetanic convulsions, etc.) not brought about the death of these patients, they would have recovered from their pulmonary involvement. It is possible to assume from these cases and incidents that the prognosis is influenced not only by the degree of the allergic inflammatory reaction resulting from massive tuberculinization but also by the specific organs involved.

The possibility that there was a pre-existing hypersensitivity to nontuberculous allergins has been studied in the cases here presented. Several others not presented and only one of those presented admit to a history of "hay fever" or "allergy"; namely, the case of M. B. (pollenosis, to tall or low ragweed). This particular patient, incidentally, exhibited the most striking and typical reaction of all living patients who had autotuberculinization and yet survived.

There is no apparent specific treatment. Oxygen therapy, intravenous fluids, and transfusions appear helpful. The administration of antihistaminic drugs might be tried on an experimental basis. We employed Benadryl on one occasion. The result was dramatic but whether this dramatic improvement can be attributed to the effect of the Benadryl is certainly open to doubt.

REFERENCES

1. Chase, W. M.: Proc. Soc. Exper. Biol. & Med. 52: 238, 1943.
2. Chase, M. W.: Proc. Soc. Exper. Biol. & Med. 59: 134, 1945.
3. Furcolow, M. L., Howell, B., Nelson, W. E., and Palmer, C. B.: Pub. Health Rep. 56: 1082, 1941.
4. Jennings, F. B., Jr., and Downing, L. M.: Bull. Johns Hopkins Hosp. 53: 172, 1933.
5. Judd, A. R.: J. THORACIC SURG. 13: 249, 1944.
6. Kane, L. W.: New England J. Med. 232: 728, 1945.
7. Landsteiner, K., and Chase, M. W.: Proc. Soc. Exper. Biol. & Med. 49: 688, 1942.
8. Lewis, J. H., and Seibert, F. B.: J. Immunol. 20: 201, 1931.
9. Levine, M. I., and Sackett, M. F.: Am. J. Dis. Child. 64: 1014, 1942.
10. Moro and Keller: Quoted by Urbach.[19]
11. Oatway, W. H., Jr., Gale, J. W., and Mowry, W. A.: J. THORACIC SURG. 13: 1, 1944.
12. Pinner, M.: Pulmonary Tuberculosis in the Adult: Its Fundamental Aspects, Springfield, Ill., 1945, Charles C Thomas.
13. Rich, A. B.: Acta Paediat. 16: 1, 1933; Physiol. Rev. 21: 70, 1941.
14. Rich, A. R., Chesney, A. M., and Turner, T. B.: Bull. Johns Hopkins Hosp. 52: 179, 1933.
15. Seibert, F. B.: Proc. Soc. Exper. Biol. & Med. 30: 1274, 1933.
16. Seibert, F. B.: Am. Rev. Tuberc. 30: 713, 1934.
17. Seibert, F. B., and Nelson, J. W.: Proc. Soc. Exper. Biol. & Med. 49: 77, 1942.
18. Tuttle, W. M., O'Brien, E. J., and Graham, E. A.: J. THORACIC SURG. 6: 544, 1937.
19. Urbach, E., and Gottlieb, P. M.: Allergy, ed. 2, New York, 1946, Grune & Stratton, Inc.

DISCUSSION

DR. ARTHUR VORWALD, Saranac Lake, N. Y.—I should like to ask Dr. Judd, whether he has factual evidence of an increase in tuberculin throughout the body. I should like to know whether he has demonstrated excessive excretion in the urine, in the sputum, and in the blood of the postoperative patients whom he describes.

DR. JUDD.—There are a great many problems in this field and a great many questions to be answered that are of special interest to the thoracic surgeon. Dr. Vorwald has just presented in his question one of these which I cannot answer. I am sorry that it is impossible to say how much tuberculin is in the system and how much is excreted, as I am aware of no known available means of making such determinations.

CYSTIC DISEASE OF THE LUNG

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Honolulu, T. H.

THE surgical treatment of pulmonary cystic disease coincident with surgical diseases of the chest in general has been receiving increasing attention. While the condition is relatively rare, it should not be lost sight of because of the dramatic response to surgical intervention in most instances. Koontz[1] was the first in the American literature, in 1925, to draw attention to this condition and since that time numerous articles have appeared discussing various aspects of the disease though no one has reported any large series of cases. At the Mayo Clinic, over a ten-year period previous to 1947, Moersch and Clagett[2] reported forty-four cases of the bronchiogenic type verified by surgical intervention. This is the largest series that I have found in the literature.

There has been a great deal of confusion though much discussion regarding many aspects of this disease. It is frequently difficult or impossible to determine whether or not a given cyst (or cysts) is congenital or acquired and what relationship it may have to some other pulmonary lesion such as bronchiectasis or lung abscess.

As Naclerio and Langer[3] pointed out, the term cystic disease of the lung has been used to designate various pulmonary lesions such as congenital pulmonary cyst, cystic bronchiectasis, epithelized cavities following pulmonary suppuration, pneumatocele (localized alveolar or lobular ectasia), chronic interstitial pneumonitis with emphysema, emphysematous bullae, and pulmonary blebs. They defined pulmonary cysts as a pathologic entity that includes abnormal localized distentions of the various portions of the tracheobronchial tree and other discrete sacs originating from the interstitial portion of the lung.

Klosk, Bernstein, and Parsonnet[4] defined cystic disease of the lung as any condition in which the lung or parenchyma is replaced by sharply defined cavities containing fluid or air. Moersch and Clagett[2] used the term "pulmonary cyst" to indicate all those abnormalities of the pulmonary tissue in which cysts or cystlike structures of the lung or bronchi are found regardless of their pathogenesis exclusive of such specific entities as tuberculous cavities, parasitic cysts, carcinoma of the lung that has undergone cavitation, and ordinary pulmonary abscess. Mediastinal cysts are also not included. Their designation that all pulmonary cysts can essentially be divided into two chief types—first, those that originate from the bronchial tree and, second, those that are alveolar in origin—seems logical and has the distinct advantage of simplicity.

Bronchiogenic cysts (Figs. 2, 7, 12, 13) are characterized by their walls being made up of elements of the bronchus—namely, cartilage, smooth muscle, elastic tissue, and mucous glands—and are lined by cuboidal or columnar epithelium which may or may not be ciliated. These cysts may contain fluid, pus, blood, or air alone or in combination.

From The Clinic, Honolulu.

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Alveolar cysts, on the other hand, do not possess an epithelial lining but are lined by alveolar cells (Fig. 17) that are compressed together to form the wall and they always contain air.

This classification seems adequate and will be adhered to in this discussion.

Probably the vast majority of cystic lesions involving the lung give rise to no symptoms and only some complicating factor draws attention to their presence. This may result from:

1. Infection.
2. Hemorrhage.
3. Air becoming trapped in the cyst, causing it to increase to sufficient size to produce embarrassment of the cardio-respiratory mechanism.
4. Rupture of the cyst wall, resulting in simple or tension pneumothorax with or without empyema.

Undoubtedly all cysts or cystlike structures are connected with a bronchus. This connection may be perfectly evident when the cyst is within the lung parenchyma and apparently has arisen within a bronchus, but this communication with the bleb and bullous-like structures arising on the surface of the lung may be difficult or impossible to demonstrate. Only by serial microscopic study have some observers been able to demonstrate this connection. If there were not some communication between bronchus and cyst these bleb-like structures would not continue to distend with air and would ultimately collapse from air absorption for they rarely contain fluid. This communication with a bronchus invites infection. In twenty-two surgically treated patients reported upon by Dickson, Clagett, and McDonald,[5] all but three were infected. In the bullous type of cyst, arising in the subvisceral pleural areas, infection is less prone to occur, undoubtedly because of the small communication with a bronchus.

Hemoptysis in varying degree is frequently observed. Ten of the twenty-two cases just mentioned presented this complication. Usually only a blood tinged sputum is noted but the bleeding may be exsanguinating.

When the cyst communicates with a bronchus by way of a valvelike mechanism so that on inspiration air is drawn into the cyst and on expiration the air cannot escape, the cyst will increase in size to a greater or lesser degree with corresponding collapse of the associated lung and shift to the opposite side of the mediastinal structures. Dyspnea and cyanosis may, and frequently does, result but it is surprising to what an extent this may take place without producing appreciable symptoms as was the case in one of our patients.

When the cyst wall ruptures, pneumothorax results which may produce respiratory difficulty particularly if it is of the tension type. If the cyst is infected, empyema will result and many cases of this type have been treated without the nature of the primary lesion being suspected. Needless to say, unless the cyst is adequately dealt with, a successful outcome is not to be expected.

SYMPTOMS

With this brief outline of the pathologic aspects of the disease, the symptoms that are produced are not difficult to anticipate.

When the cyst or cysts are small and uncomplicated no symptoms are to be expected and a diagnosis, if ever made, will be accidental and on the basis of x-ray interpretation.

When infection occurs, and this is prone to take place when the cyst has an open connection with a bronchus, the symptoms are those of recurring pneumonia or pneumonitis, chronic bronchiectasis, or pulmonary abscess with associated cough, fever, chills, expectoration of purulent sputum, and leucocytosis. When a blood vessel is eroded or ruptured, hemoptysis is added to the picture. With increasing size of the cysts the lung will be compressed or destroyed and the patient will then become dyspneic and cyanotic with increasing degree as the lesion progresses. As previously stated, rupture of the cyst may give rise to tension pneumothorax or empyema. Pain apparently is not an outstanding feature of the lesion but may occur, particularly if there is an inflammatory involvement of the pleura.

DIFFERENTIAL DIAGNOSIS

A correct diagnosis of pulmonary cystic disease may be extremely difficult or impossible to make without surgical exploration. Keeping the possibility of such a lesion in mind will go a long way toward arriving at a correct interpretation of the picture. As might be expected from the symptoms produced, a diagnosis of pulmonary tuberculosis is probably the most common error made. Lung abscess, bronchiectasis, spontaneous pneoumothorax, empyema, carcinoma of the lung, substernal thyroid, and various mediastinal tumors may all come up for consideration.

DIAGNOSIS

As stated, the history of pulmonary cystic disease contains no characteristic symptoms and neither does the physical examination. The most important investigation in these cases is, of course, by x-ray study of the chest. This is frequently confusing though at times quite diagnostic. If the cyst is filled with fluid its true nature can only be surmised; when the cyst is empty the diagnosis may be evident.

Large solitary cysts frequently occur in very early childhood and they are characterized by large areas of radiolucency (Fig. 8) and may or may not show fluid. They are frequently traversed by linear strands of trabeculation without any evidence of pulmonary markings. When these cysts are ballooned out by high intercystic pressure (Fig. 14) as is most likely to occur in the alveolar type, the picture resembles that of pneumothorax. The lung is compressed and there is greater or less shifting of mediastinal structures to the opposite side.

When the lung contains many cysts, it is characterized by a honeycombed (Figs. 1, 2, 3) appearance, with radiolucent areas of varying sizes. An important characteristic of pulmonary cystic disease is that the lesion or lesions are usually confined to one lobe or a segment of a lobe and that there is little or no inflammatory change in the adjacent lung or pleura. Bronchography may be of aid in determining the nature of the pulmonary lesion, particularly if the cyst has a sufficiently large connection with a bronchus to permit its visualization.

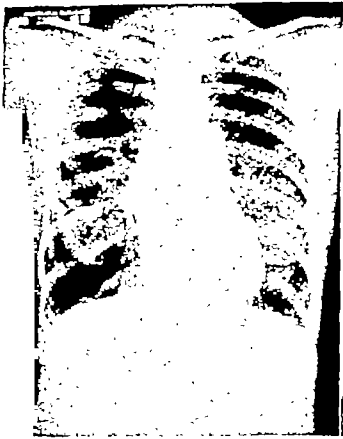

Fig. 1.

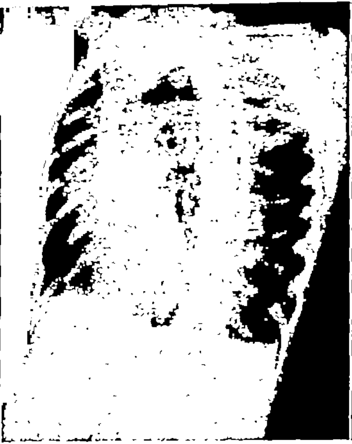

Fig. 2.

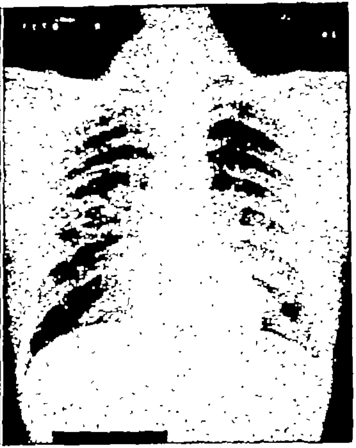

Fig. 3.

Figs. 1 and 2.—Cysts involving right middle lobe of lung associated with attacks of severe hemoptysis.

Fig. 3.—Multiple cysts involving right upper lung, causing no symptoms and found accidentally on routine x-ray examination of chest.

At times it is difficult even impossible, to determine whether or not a given lesion is in the mediastinum or within pulmonary tissue. Introducing air into the pleural cavity, particularly if no adhesions are present, may be of distinct value in determining this point.

Bronchoscopy offers little in the diagnosis of cystic disease but it may be of value in ruling out or affirming an intrinsic bronchial lesion such as neoplasm.

Measurement of the intracystic pressure before and after aspiration of air may or may not be of value in differentiating between a cyst and a localized pneumothorax. If the cyst is connected with a bronchus no decrease in pressure following aspiration of air will occur, while a distinct reduction is to be expected in localized pneumothorax. If the cyst is of the alveolar type with minute bronchial connection this differentiating evidence probably will not be manifest. Introducing iodized oil directly into the cyst will outline its wall, and strands of tissue traversing the cyst may be well visualized and be of distinct aid in diagnosis. Some observers consider the visualization of these strands to be pathognomonic of the presence of cystic disease. Puncturing such cysts is not without danger because of the possibility of infecting the pleural cavity or of producing tension pneumothorax. Thoracoscopy has the same inherent dangers and probably does not add enough additional information to justify its use.

As Maier and Haight[6] and others have pointed out, the differential diagnosis between large infected solitary cysts and empyema is at times extremely difficult, even impossible, to make preoperatively and the true nature of the lesion, even at operation, may not be recognized. With the present infrequency of empyema following pneumonia due to the use of antibiotics, this problem is less frequently encountered.

In cystic disease in contrast to the picture produced by empyema, the outline of the cyst is more likely to be spherical. Regardless of the length of time of infection there is usually little reaction either in the pleura or surrounding pulmonary tissue. Strands of pulmonary tissue are frequently seen traversing the cyst and cysts may be evident in other parts of the lung.

At operation, lack of pleural reaction is noted and the cyst wall is typically shiny, smooth, and glistening in contrast to either an empyema or abscess cavity where the pleura is thick and the wall of the cavity is edematous and granular. If doubt exists as to the true nature of the lesion a biopsy of the wall should be made since the presence of ciliated epithelium leaves no doubt as to the correct diagnosis.

Maier and Haight[6] have found that if the condition is not recognized and is treated as an empyema, a striking feature in the postoperative course is the failure of the cavity to diminish progressively in size despite adequate drainage for months or years. The cavity tends to retain its spherical form; the pleura shows relative lack of thickening, and the diaphragm is not elevated to the extent that occurs in empyema. The discharge from the cavity of a drained cyst is mucoid and less purulent than that from an empyema.

All individuals whose cystic disease produces symptoms should in all probability be subjected to surgery if they are physically fit. In individuals in whom the disease is more or less found accidentally during the course of a routine examination, this advice may be open to argument. Serious complications, as previously mentioned, may occur, and some observers are of the opinion that malignancy is prone to take place in the cyst wall. The surgeon is usually spared the responsibility of making the decision by the patient's refusing any operative intervention, if he is asymptomatic.

CASE REPORTS

CASE 1.—A Japanese girl, aged 13 years, first came under observation on Oct. 20, 1945. The patient's illness had began two months previously with fever, sweats, productive cough of thick mucopurulent sputum, and on one occasion she expectorated a small amount of bright red blood. When 3 or 4 years of age, the patient developed pneumonia followed by pus in the left side of the chest which had been drained surgically. During the recent illness she had been hospitalized by her family physician who had made a diagnosis of left lung abscess and treated her with penicillin for several weeks without improvement. Repeated examination of sputum had shown no tubercle bacilli.

On physical examination there was dullness to percussion in the left lower part of the chest with absent breath sounds. X-ray pictures of the chest showed a large cavity with a fluid level which occupied the lower half of the lung field (Figs. 4 and 5).

The patient had lost considerable weight and had a daily temperature of 99° to 100° F. It was thought best to drain the abscess cavity, which would also permit a certain amount of investigation of the lesion as an aid in determining the future course to pursue. Accordingly, on Nov. 2, 1945, portions of the eighth and ninth ribs in the axillary area were resected and the cavity entered through adherent pleura.* The cavity contained thick pus. Its walls were smooth and velvety and gave the appearance of a cyst rather than a lung abscess.

The patient made satisfactory improvement following the drainage operation and three months later the left lower lobe which contained many cysts of varying size was removed (Fig. 6). The patient's postoperative course was prolonged by the development of an empyema but she made a good recovery and has since remained well.

Pathologic Report.—The specimen, consisting of the left lower lobe of the lung, contained several large cystlike structures, the largest of which measured 6 cm. in diameter. On section these cystlike structures were found to be dilated bronchi which were thickened in some areas and thinned in others. The surrounding lung tissue showed areas of atelectasis and emphysema. Histologic examination of the lung showed a typical bronchiectatic process which represents a chronic inflammatory reaction, moderate fibrosis, cystic dilatation of bronchioles, and chronic compensatory emphysema (Fig. 7).

CASE 2.—J. M., a 2½-month-old baby girl, was first seen at The Clinic on March 27, 1940. The patient had been well until the past two weeks, when the parents noticed that she was having increasing respiratory distress. Breathing had become rapid and shallow and the patient cyanotic. Examination revealed hyperresonance to percussion over the left side of the chest with absent breath sounds. Heart sounds were best heard to the right of the sternum. X-ray view of the chest showed the left pleural cavity devoid of lung markings with displacement of the heart and other mediastinal structures to the right (Fig. 8). It was thought that the patient was suffering from either cystic disease of the lung, spontaneous pneumothorax, or a large diaphragmatic hernia. Barium by mouth and per rectum revealed nothing suggesting a hernia. Aspiration of 275 c.c. of air from the left side of the chest caused no change in the patient's symptoms or x-ray findings. Under local anesthesia, a mushroom catheter was inserted into the chest and subsequent x-ray studies showed that the catheter had entered a pulmonary cyst but that there were other much larger cysts that were still distended. Some improvement in the patient's condition occurred but this was not

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*Operation by Dr. Burgess.

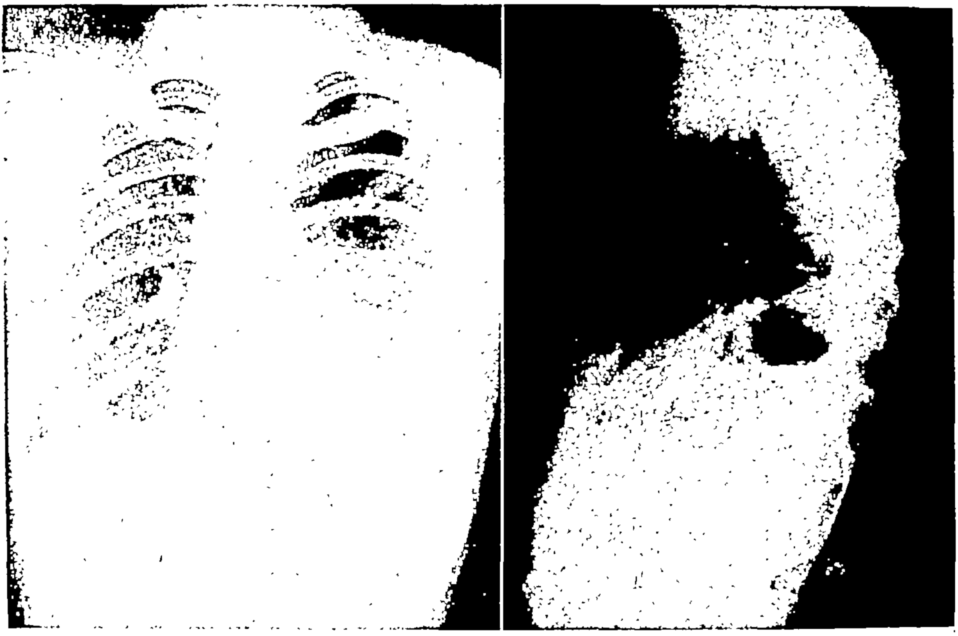

Fig. 4. Fig. 5.

Figs. 4 and 5 (Case 1).—Cyst involving left lower lobe of lung partially filled with fluid and mistaken for lung abscess.

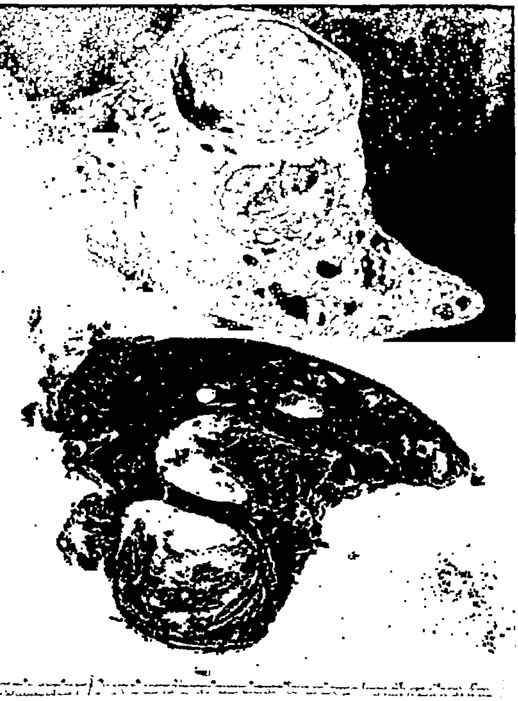

Fig. 6.

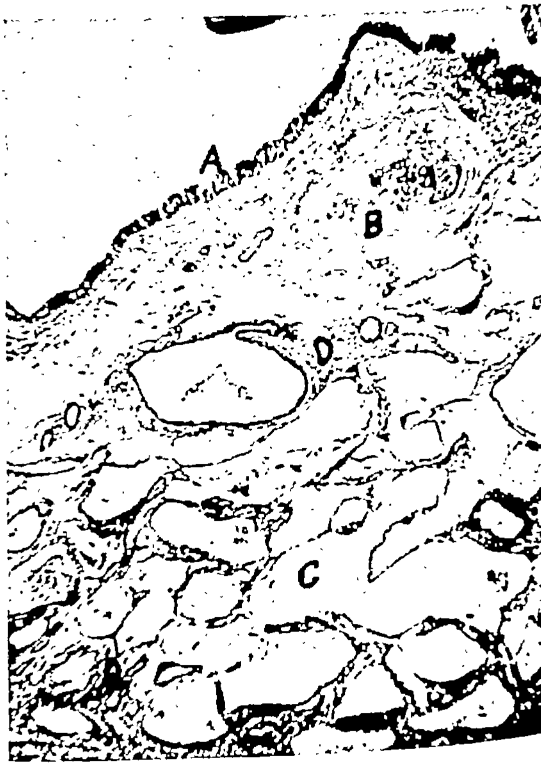

Fig. 7.

Fig. 6 (Case 1).—Left lower lobe of lung removed at operation, filled with cysts of bronchiogenic type.

Fig. 7 (Case 1).—Photomicrograph of cyst wall showing *A*, pseudostratified columnar epithelium; *B*, bronchial cartilage; *C*, emphysema; *D*, fibrosis.

lasting so the catheter was removed after four days and the patient's respiratory distress and cyanosis were relieved by intermittent aspiration of air from the cysts. The patient's general condition was extremely poor from the beginning so that any major operative interference scarcely seemed justified, and various supportive measures did not improve the situation, as might be expected. Two weeks following attempt at relief of intrathoracic pressure by catheter drainage, it was decided that more radical measures were in order because the cysts had become infected and the patient's condition was, to say the least, not improved.

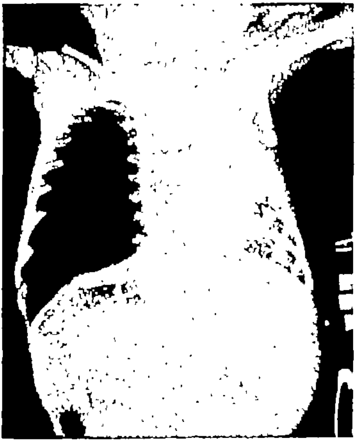

Fig. 8 (Case 2).—Large solitary cyst (bronchiogenic type) involving the left lower lobe, completely filling the left pleural cavity, and displacing mediastinal structures markedly to the right.

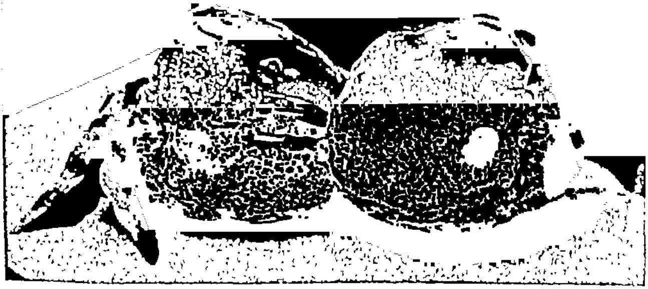

Fig. 9 (Case 2).—Photograph of left lung removed at operation; upper lobe at left.

Under local anesthesia, the sixth rib was resected and the left lung, containing the cysts, easily delivered and removed (Fig. 9).* Since there were no adhesions between the cysts and the parietal pleura, it was easier to remove the whole lung than the involved lung

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*Operation by Dr. Burgess.

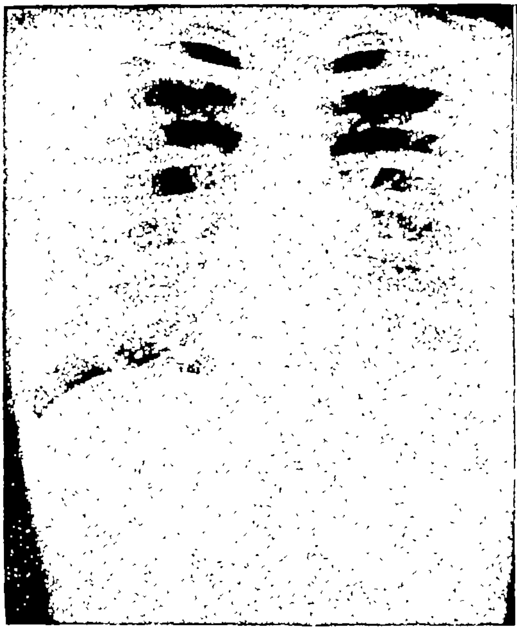

Fig. 10.

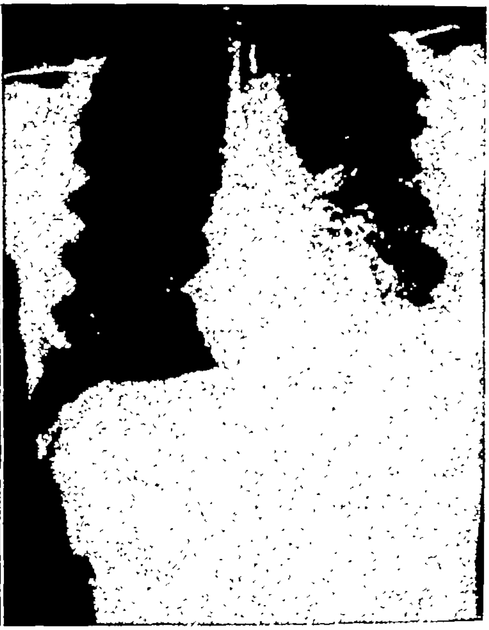

Fig. 11.

Fig. 10 (Case 3).—X-ray view of chest showing dense shadow in left lower chest (atelectasis or fluid).

Fig. 11 (Case 3).—Bronchogram of left lower lobe showing dilated bronchi (bronchiogenic cysts).

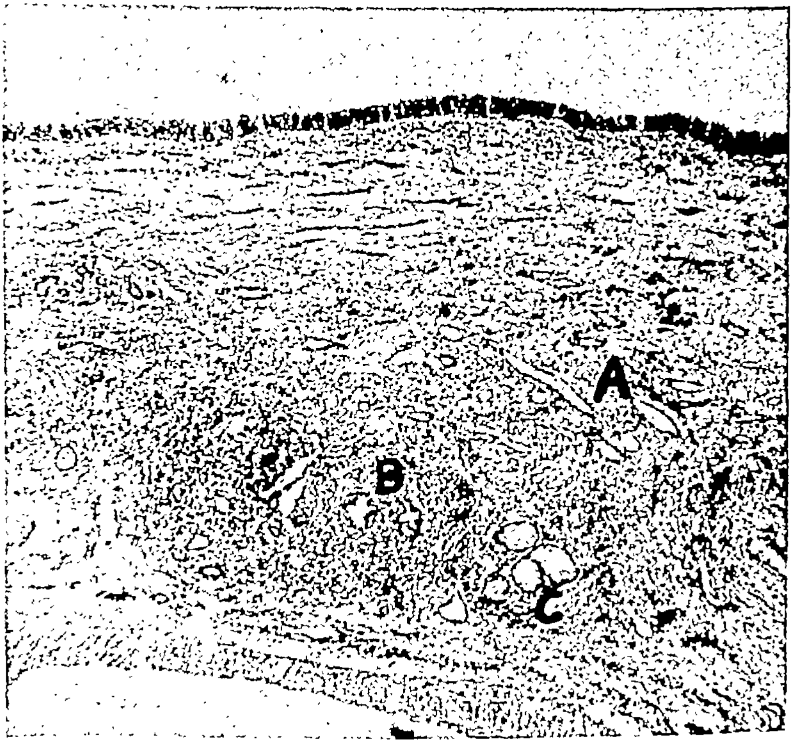

Fig. 12 (Case 3).—Photomicrograph of cyst wall lined with columnar epithelium. Lung parenchyma has been destroyed and replaced by fibrous tissue containing many small blood vessels (*A*), lung bronchioles (*B*), and mucus glands (*C*). There is much lymphocytic infiltration.

lobe. The chest was drained. The patient did well for the first four postoperative days. The respiratory embarrassment and accompanying cyanosis were relieved. However, she again became cyanotic and x-ray study showed an increasing shadow about the heart and a diagnosis of pericarditis was substantiated by pericardial aspiration.

The patient died on the seventh postoperative day and autopsy revealed marked purulent pericarditis cultures from which showed pure *Staphylococcus aureus.*

Sections of the cyst showed it to be lined with ciliated columnar epithelium and the walls were typical of the bronchiogenic type.

CASE 3.—V. S. was a 13-year-old Chinese girl. Except for pneumonia at the age of 2 years the patient was well until the age of 7, when she "caught cold" and developed a cough accompanied by spiking fever which lasted for three months. After this time the history was one of repeated prolonged head colds with cough productive of mucopurulent sputum, associated with low-grade fever. One year previously the tonsils and adenoids had been removed and following this the symptoms had been aggravated, with pain in the left side of the chest at intervals. At the time of examination and for several days previous to surgery, while hospitalized, the temperature varied between 99° and 100° F.

Physical examination revealed coarse and fine râles over the left lower chest in the axillary region and posteriorly. There was dullness to percussion over the base of the lung on the left. Sputum examinations for tubercle bacilli were negative. X-ray view of the chest showed a dense shadow in the region of the left lower lobe due to either atelectasis or fluid, and bronchograms showed bronchiectasis involving the left lower lobe (Figs. 10 and 11).

Previous to surgery, postural drainage was attempted but was unsuccessful. For forty-eight hours before operation the patient was given 20,000 units of penicillin every four hours. At operation on June 15, 1946, the left lower lobe and lingula were removed. The lingula was completely atelectatic but contained no bronchiectasis or cysts. The lower lobe contained many dilated bronchi (cysts) filled with mucopurulent fluid, the largest of which measured 8 cm. in diameter. There were focal areas of atelectasis, dilated and thickened bronchioles, and multiple miliary abscesses (Fig. 12).

The patient made a good recovery and has since remained well.

CASE 4.—J. M., a 26-year-old white man, was first seen at The Clinic* on Sept. 9, 1933, with a history of intermittent mild hemoptysis of two years' duration. X-ray and fluoroscopic study of the chest revealed cloudiness in the region of the right middle lobe, the nature of which was in doubt. Tuberculosis was suspected but no evidence to support this suspicion could be elicited. The cloudiness in the right side of the chest gradually cleared up but the patient continued to have frequent bouts of colds associated with cough and expectoration of bloodstreaked sputum. In the early part of 1943 while living on another island the patient developed moderate exertional dyspnea without other symptoms and, following x-ray examination, he was told that he had a collapsed left lung. Findings from a bronchoscopic examination at this time were reported to be negative.

In December, 1946, the patient was again hospitalized* because of an upper respiratory infection. X-ray study of the chest at this time suggested that the patient had a spontaneous collapse of the left lung possibly associated with cystic disease.

A needle was introduced into the left chest and pressure readings ranged from plus 5 cm. of water to minus 5 cm. of water, and this did not change after withdrawal of 300 c.c. of air and finally 500 c.c. It was felt at this time that the needle was in communication with a bronchial fistula, whether by way of the pleural cavity or by way of a cyst seemed debatable. From subsequent findings at operation the needle undoubtedly was within a cyst.

The x-ray pictures showed strands of what was thought might be adhesions between the collapsed lung and chest wall. With the idea in mind that possibly an adhesion might be a contributing factor in keeping open a bronchopleural fistula and, if so, severing it might be advantageous; that we might be able to see the fistula, if present, and that if we

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*By Dr. Doolittle.

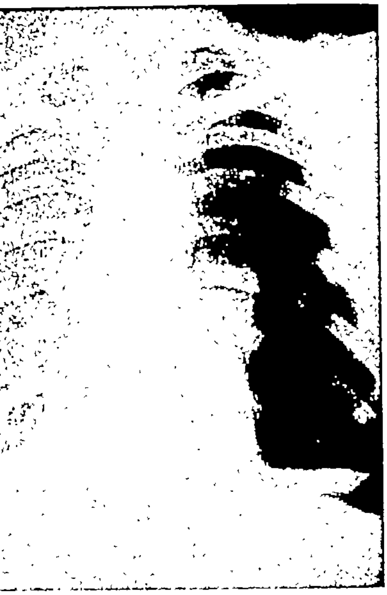

Fig. 13.

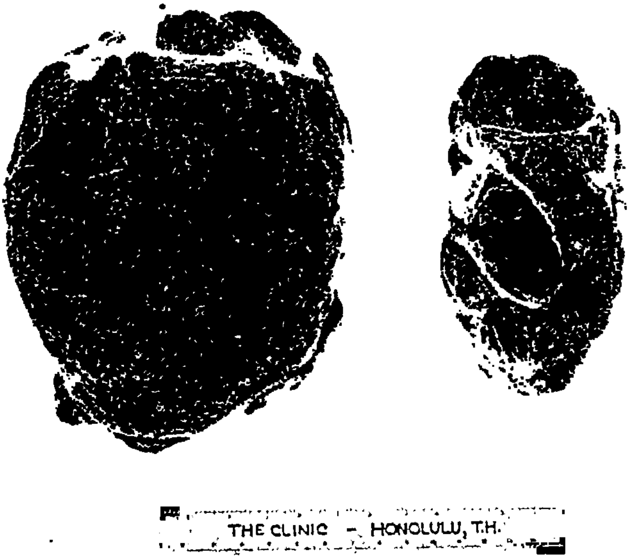

Fig. 14.

Fig. 13 (Case 4).—Roentgenogram of chest showing collapsed left lung with little displacement of mediastinal structures. The lower cyst wall has been outlined following introduction of 100 c.c. of blood into cyst.

Fig. 14 (Case 4).—Photograph of largest cysts removed at operation.

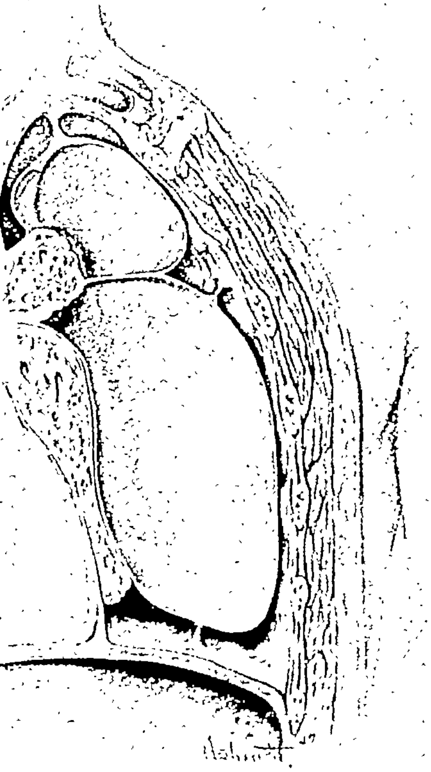

Fig. 15.

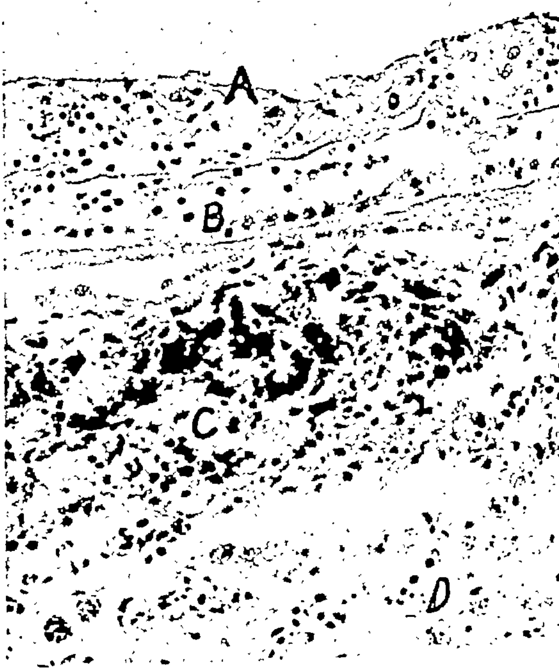

Fig. 16.

Fig. 15 (Case 4).—Drawing illustrating condition found at operation, showing two large cysts (alveolar type) arising from the upper lobe. Both lobes of the lung collapsed from pressure by the cysts.

Fig. 16 (Case 4).—Photomicrograph of cyst wall (alveolar type) showing (*A* and *B*) thin membrane of proliferated alveolar cells, (*C*) atelectatic and anthracotic lung, and (*D*) fairly normal-appearing lung parenchyma.

were dealing with cystic abscess of the lung this might be determined, a thoracoscopy was done.

The thoracoscope, which was introduced anteriorly above the nipple in the second interspace and also in the axillary area in the third interspace, undoubtedly entered directly into the large bullous cavity that was subsequently found at operation. No adhesions that were amenable to cauterization were visualized and no fistulous communication with a bronchus could be found. The fact was not appreciated that the thoracoscope had entered a tremendous alveolar type of cyst. It was still believed that probably a tension pneumothorax was being dealt with which had completely collapsed the lung and that failure of the lung to re-expand was due to a pleural fistula remaining patent. With the hope of setting up a pleural reaction that might be productive enough to aid in closing a small bronchial fistula, 100 c.c. of the patient's own blood in 5 c.c. of sodium citrate was introduced into the left chest. Roentgenogram following this procedure, it was felt, definitely outlined a cyst wall (Fig. 13) and it was decided that exploration of the chest was indicated.

On Jan. 13, 1947, the chest was explored through a lateral incision, resecting the seventh rib.

Two immense cystlike structures filled with air and several smaller ones were found, completely filling the left chest (Figs. 14 and 15) and arising from the left upper lobe. Both lobes were completely collapsed, being compressed against the mediastinal structures. Undoubtedly these bullous structures simply represented visceral pleura that had been lifted up from the lung and continued to distend with air by a ball valve mechanism communicating with bronchioles. Where these cystic structures were attached to the lung there was no wall—simply compressed alveoli. No gross communication with bronchi was visible. These bullae were easily removed and the areas of denuded lung were sewn over with atraumatic chromic catgut. No lung tissue was sacrificed. It was gratifying to see how completely the lung distended and filled the entire chest under positive pressure through the intratracheal tube, even though it had been collapsed for a period of four years. Microscopic study confirmed the diagnosis of alveolar type of cyst (Fig. 16).

The patient made an uneventful postoperative recovery. Subsequent x-ray studies showed the lung completely expanded and the patient to date (one year postoperatively) has remained well.

This case illustrates how little discomfort the patient may experience from cystic disease of the lung even though complete collapse of a lung takes place. This undoubtedly was due to the insidious progress of the disease and to the small amount of mediastinal displacement that took place. This is also a good example of how completely a lung will re-expand after being collapsed for years so long as no infection has occurred to produce pleural thickening or inflammatory reaction in the lung parenchyma.

DISCUSSION

It is evident from a perusal of current literature and from our limited experience that the clinical entity of pulmonary cystic disease even when producing symptoms frequently remains unrecognized. This is largely due to the relative infrequency of the disease and the clinicians' corresponding lack of acuity in bearing the possibility in mind. Since the lesion commonly occurs in infancy and early childhood, the onset of dyspnea and cyanosis in the absence of a cardiac lesion to account for those symptoms should arouse one's suspicions regarding pulmonary cystic disease. At any age spontaneous pneumothorax or x-ray findings indicative of this condition should suggest such a possibility. Patients with hemoptysis in whom tubercle bacilli are constantly absent from the sputum and whose x-ray pictures are atypical should be carefully studied with the possibility of cystic disease in mind.

All patients in whom a diagnosis of empyema is made, particularly those who do not give a typical history of previous pneumonia, should be carefully scrutinized for the possibility of cystic disease as an etiological factor. Lack of the usual pulmonary and pleural reaction around a suspected lung abscess or empyema or other suspected inflammatory lesion of the chest should arouse one's curiosity as to the possibility of cystic disease. An adequately drained lung abscess or empyema that does not respond well should be explored and the wall of the cavity biopsied to rule out cystic disease.

After all is said and done, the fact remains as evidenced by reports from many outstanding chest clinics, that pulmonary cystic disease masquerades under the guise of many other diseases and that even in the hands of those most competent the true nature of the lesion may long go undiagnosed. Bearing in mind the possibility of this condition being present will go a long way toward preventing a mistaken diagnosis.

It is particularly desirable to diagnose these lesions correctly because of such gratifying results to be expected from surgery. It is mandatory that some of the more acute cases be recognized quickly for any therapeutic measure to be life-saving.

ADDENDUM

Since this paper was prepared, two additional patients with pulmonary cystic disease have come to surgery. One, a 13-year-old boy with cysts of the bullous type involving the left lung and causing respiratory embarrassment, made an uneventful recovery following pneumonectomy. The second, a 16-year-old Japanese girl, who had been under observation for several months with an increasing shadow in the right upper apex, came under my care after the cyst had ruptured into the pleural cavity. Following the subsidence of this acute episode, she made an uneventful recovery following removal of the right upper lobe. This represented the bronchiogenic type of pulmonary cystic disease.

REFERENCES

1. Koontz, A. R.: Congenital Cystic Disease of the Lung, Bull. Johns Hopkins Hosp. 37: 340, 1925.
2. Moersch, H., and Clagett, O. T.: Pulmonary Cysts, J. THORACIC SURG. 16: 179-199, 1947.
3. Naclerio, E., and Langer, L.: Pulmonary Cysts: Special Reference to Surgical Treatment of Emphysematous Blebs and Bullae, Surgery 22: 516-524, 1947.
4. Klosk, E., Bernstein, A., and Parsonnet, A. E.: Cystic Disease of the Lung, Ann. Int. Med. 24: 217-232, 1946.
5. Dickson, J. A., Clagett, O. T., and McDonald, J. R.: Cystic Disease of the Lung and Its Relationship to Bronchiectatic Cavities, J. THORACIC SURG. 15: 196-204, 1946.
6. Maier, H., and Haight, C.: Large Infected Pulmonary Cysts Simulating Empyema, J. THORACIC SURG. 9: 471-492, 1940.
7. Gross, R. E.: Congenital Cystic Lung: Successful Pneumonectomy in a Three Week Old Baby, Ann. Surg. 123: 229-237, 1946.

GLOMUS TUMOR OF THE MEDIASTINUM

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WOOD,[1] in 1812, made the original clinical description of glomus tumors but Masson,[2, 3] in 1924, was the first to describe accurately the normal glomus and to indicate the relationship between this structure and the glomal tumor. Since these original descriptions, relatively few cases have been reported. These tumors occur most frequently in the extremities and I have found no report in the literature of a glomus tumor of the mediastinum.

The normal glomus consists of several component parts, the afferent arteriole; the anastomotic vessel or Souquet-Hoyer canal; collecting veins; numerous, nonmedullated nerves; and the reticular supporting structure of the glomus.

Popoff[4] reported that the glomus is absent at birth but develops rapidly postnatally and begins to undergo atrophy around 60 years of age. Apparently the normal function of the glomus is to assist in the regulation of heat in the body and control of blood pressure. Heat control is probably the main function.

The glomal tumor represents a benign hyperplasia of all the elements in the normal glomus. Distribution as to sex has been about equal and tumors have been reported in patients from 1 to 80 years of age.

Tumors of the neuromyoarterial glomus are small in size, varying from a few millimeters to 3 cm., and their color is usually purple or deep red. These lesions occur rarely in Negroes and some[6] feel they are more frequent in Jews. The etiology of glomus tumors[7] has not been established, although some observers report a 40 to 50 per cent incidence of trauma prior to the development of the tumor of the glomus.

Pain is the outstanding symptom and is usually spontaneous or easily induced by slight pressure. Most of the recorded cases have a history of rather severe painful crises with radiation of the pain.

Glomus tumors are considered benign and I have not found any report of a case in which metastasis has occurred. These lesions are radioresistant and neither x-ray nor radium has been successful in their removal. Due to the benign, localized nature of the lesion, complete surgical excision is the ideal treatment and results in a permanent cure.

I wish to present a report of a patient who had glomus tumors removed from the mediastinum and the right lower extremity with complete relief of symptoms.

CASE REPORT

A 29-year-old white woman entered the Clinic Feb. 10, 1947, with the chief complaint of pain in the right lower part of the chest for nine years. The pain was always present but not constant in severity. It was sharp and associated with paroxysms of rather severe pain, requiring sedation for relief. Coughing or motion increased the discomfort and heat seemed to lessen it.

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From the Department of Surgery of the Scott & White Clinic.

Fig. 1.

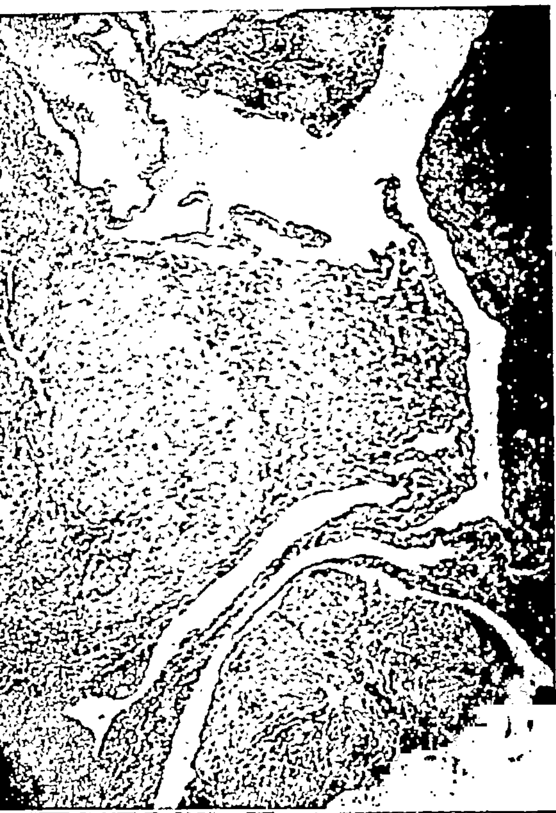
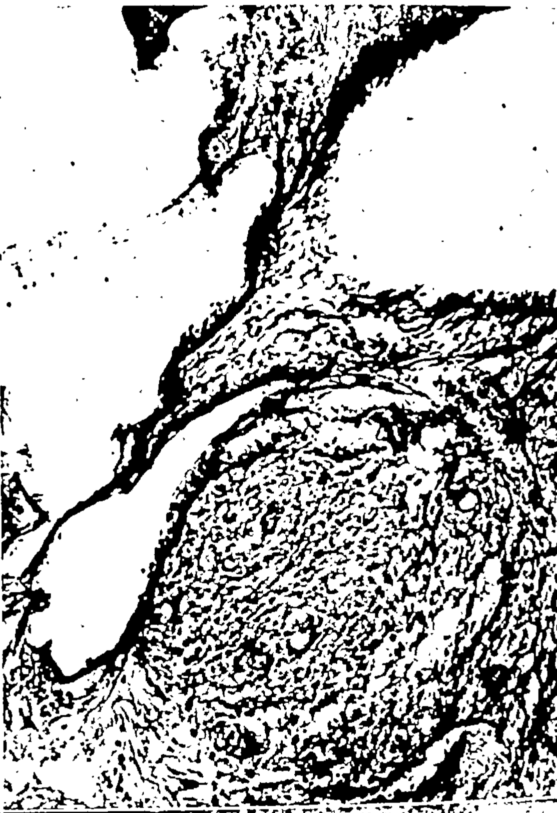


Fig. 2.



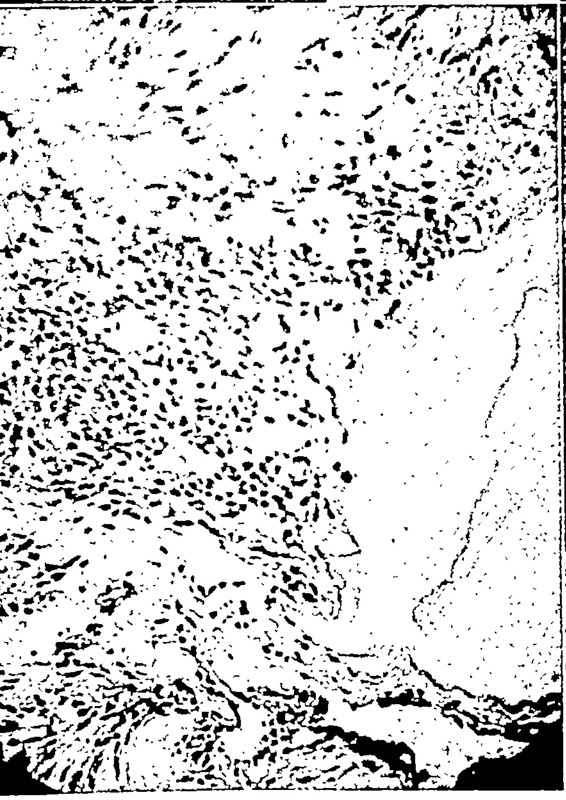


Fig. 3.

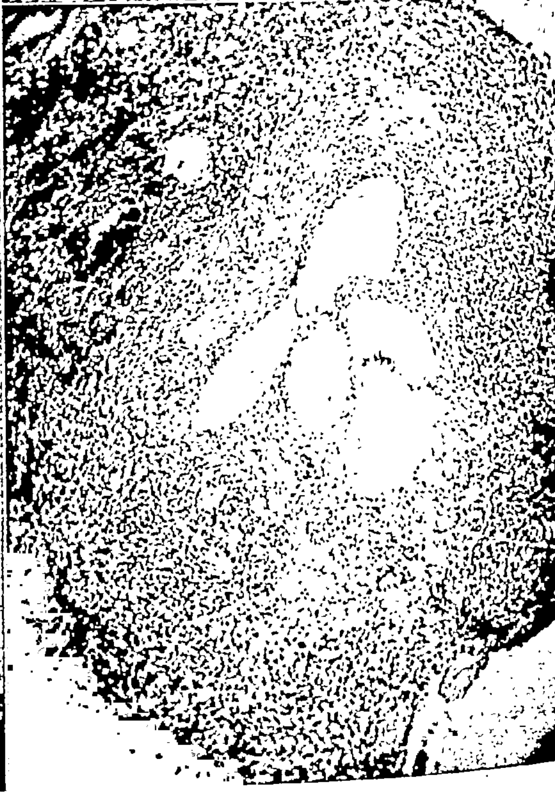


Fig. 4.

Fig. 1.—Glomus tumor of mediastinum. Intercommunicating vascular spaces surrounded by glomus cells and collagenous tissue containing neural fibers. (×160.)

Fig. 2.—Glomus tumor of mediastinum. Hyalinized fibrous tissue and nerve fibers surrounding vascular channels. (×440.)

Fig. 3.—Glomus tumor of the leg. Glomus cells in collagenous reticulum surrounding vascular spaces. (×440.)

Fig. 4.—Low-power view of glomus tumor of leg, showing large vascular spaces, glomus cells, nerve fibers, and supporting collagenous reticulum. (×160.)

Past history revealed that in 1945 this patient had a tumor approximately 1 cm. in size removed from the right groin. This lesion was quite tender, rounded, and purple in color; she was told that it was a hemangioma. In January, 1947, she developed several other similar tumors on the right lower extremity, extending from the mid-thigh to the ankle.

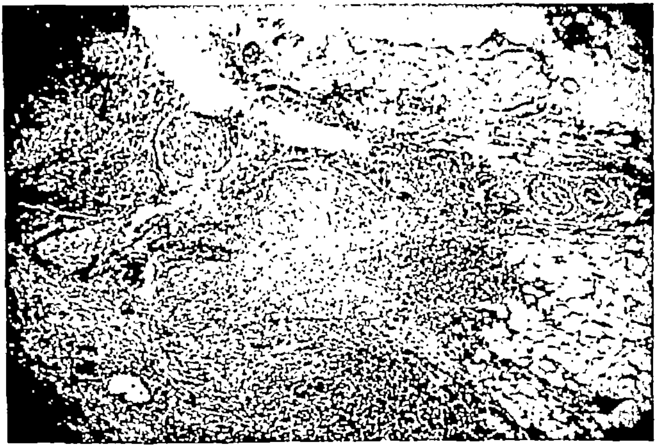


Fig. 5.—Marked thickening of arterial walls at the periphery of the glomus. (×100.)

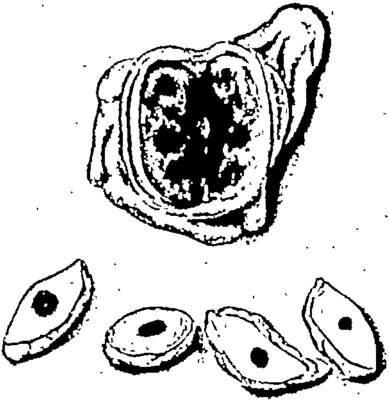


Fig. 6.—Artists' illustration of the glomus tumor of the mediastinum and four glomus tumors of the leg.

Physical examination revealed extensive mottling and pigmentation of the skin of the right chest wall from heat. Hyperesthesia was present over the right thoracic seventh to twelfth dermatomes. There were four rounded, purple, elevated, tender masses on the right lower extremity. These were all approximately 1 cm. in size. Two were on the thigh, one just below the knee, and one near the ankle.

Laboratory tests, including urinalysis, complete blood count, Mazzini serology test, spinal fluid examination, myelograms, and dorsal spine x-ray views were normal. Chest roentgenograms revealed a soft area of increased density originating close to the spine, in the posterior mediastinum, extending from the eighth to the tenth dorsal vertebrae.

On March 13, 1947, an exploratory thoracotomy was performed. When the left pleural cavity was entered, a tumor, approximately 5 by 3 cm. in size, was visualized just lateral to the eighth dorsal vertebra. The pleura overlying the tumors was incised and the tumor removed. It was apparently attached to the eighth intercostal nerve. Subsequently, the tumors from the right lower extremity were also removed.

The gross and microscopic appearance of the tumor removed from the mediastinum and those removed from the leg were identical and diagnosed by the pathologists as glomus tumors. Several prominent pathologists* in this country studied the tissues and all concurred in the diagnosis of probable glomus tumors.

Microscopic examination under the low-power objective showed the tumor to be encapsulated by connective tissue. The central portion consisted of intercommunicating vascular spaces lined by large cuboidal endothelial cells. Near the vessels were the large clear epithelioid cells, or so-called glomus cells. Surrounding the vascular spaces and among the glomus cells were numerous nonmedullated nerves. A fibrocollagenous reticulum formed the supporting structure for the tumors.

The patient's convalescence was uncomplicated and there has not been recurrence of either the tumors or pain.

CONCLUSIONS

1. Glomus tumors are benign hyperplasias of the normal constituents of the glomus.
2. These tumors occur most frequently in the extremities but may occur elsewhere in the body.
3. Due to the benign, localized nature of glomus tumors, complete surgical excision is the ideal treatment and results in a permanent cure.
4. Glomus tumors are radioresistant and radiation therapy is not effective.
5. A report has been given of a patient who had a glomus tumor of the mediastinum and similar tumors from one lower extremity removed with complete relief of symptoms.
6. A review of the literature did not reveal a previously reported case of a glomus tumor of the mediastinum.

REFERENCES

1. Wood, William: Painful Subcutaneous Tubercle, Edinburgh M. J. 8: 283, 1812.
2. Masson, P.: Le glomus neuromyo-arteriel des regions tactiles et ses tumeurs, Lyon chir. 21: 257, 1924.
3. Masson, P., and Gery, Louis: Les tumeurs glomiques sous-cutanees en dehors des doigts, Ann. d' anat. path. 4: 153, 1927.
4. Popoff, cited by Becker, F. T.: Tumors of the Neuromyo-arterial Glomus, Minnesota Med. 23: 78, 1940.
5. Fowlkes, Richard W., and Pepple, Allen W.: Tumors of the Glomus, South. M. J. 33: 269, 1940.
6. Graves, Robert C., and Burt, James C.: Unusual Location of Glomus Tumor; Report of Two Cases, J. A. M. A. 112: 1806, 1939.

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*Dr. Malcolm Dockerty of the Mayo Clinic; Dr. Paul Brindley, Professor of Pathology at the University of Texas Medical School; Dr. Charles Phillips, and Dr. Karl Schlademan of the Scott & White Clinic.

ABSTRACTS OF PAPERS READ AT THE TWENTY-NINTH ANNUAL MEETING OF THE ASSOCIATION FOR THORACIC SURGERY AT NEW ORLEANS, LA., MARCH 29, 30, AND 31, 1949

1. THE SURGICAL CORRECTION OF CONSTRICTIVE PERICARDITIS. Emile Holman, M.D., San Francisco, Calif.

In 265 reported operations for constrictive pericarditis, 21 deaths occurred on the operating table, 49 deaths occurred in the early postoperative period, 118 patients were considered cured, and 44 patients improved.

Although the thickness of the diseased pericardium varies considerably in different areas, a satisfactory and adequate pericardiectomy must include excision of the pericardium over the left ventricle, over the right ventricle and auricle, and over both venae cavae. The inferior cardiac border must be liberated by excision of the usually greatly thickened pericardium lying between the heart and the diaphragm. Failure to relieve constriction of the inferior vena cava may result in failure to correct ascites. Persistence of ascites following pericardiectomy is evidence of an inadequate decortication and demands reoperation and removal of more scar, rather than an omentopexy or Talma operation.

To achieve the exposure necessary for an adequate inspection and decortication of the heart, a median sternotomy with transverse division of the sternum in the second interspace is recommended. The sternum is reapproximated by several stainless steel sutures inserted through bone, not through avascular cartilage.

The wound should be drained, preferably into the right pleural space, from which the fluid can be removed either by aspiration or by intercostal drainage. (Paper illustrated by motion picture of three decortications—12 minutes.)

2. A METHOD FOR EXPOSURE OF THE CARDIAC SEPTA. F. D. Dodrill, M.D., Detroit, Mich.

A method has been used experimentally by which the chamber of the heart, either the right atrium or the right ventricle, is opened, the septum exposed for short intervals, and the incision closed. An instrument has been made which consists of a ring clamp on the distal end. The clamp is used to bring the lateral walls of the atria in apposition to the septum. The incision is made within the ring, which excludes the circulation from this area. Portions of the atrial septum have been excised and the defect closed. The exposure of the ventricular septum is more difficult but has been accomplished with the same instrument.

3. THE CHOICE OF THE SIDE FOR APPROACH IN OPERATIONS FOR PULMONARY STENOSIS. Conrad R. Lam, M.D., Detroit, Mich.

The experience to be presented was gained in 42 operations on 41 patients with pulmonary stenosis. Blalock operations or attempts were carried out on 34 patients. Two of five failures to complete the operation were due to inability to approximate the right subclavian and pulmonary arteries. One of these patients subsequently had a successful modified Potts operation on the left side; an anastomosis was created between the lower branch of the pulmonary artery and the descending aorta. There were two deaths from hemorrhage following completed Blalock operations on the right side in which technical difficulties due to short subclavian arteries had been encountered. This experience has led us to follow the suggestion of Holman and plan all Blalock operations for the left side if the patient has a left heart, regardless of the position of the aortic arch. Twelve of fifteen patients operated upon since that decision was made have had left arches; all had good results and in no case was it necessary to sever the pulmonary artery proximal to the anastomosis in order to gain additional length.

The Potts procedure was planned for 10 patients, mostly small children. The operation was successful in 5 patients with left arches and in 2 with complete dextrocardia. The right approach was used with complete satisfaction in the latter. However, difficulties were encountered when this approach was used in 3 patients with right arches. In 2, the Potts operation had to be abandoned because the aorta and pulmonary artery could not be approximated and unsatisfactory subclavian-pulmonary anastomoses were substituted. In the third, a poor aortic-pulmonary shunt was made with great effort, but the child died. It is believed that Blalock operations on the left side would have been preferable.

In our hands, the best results have been obtained when the operative approach is on the side of the apex of the heart, regardless of the age of the patient or the position of the aortic arch.

4. THE SURGERY OF MITRAL STENOSIS. Dwight E. Harken, M.D., Boston, Mass.

The surgery of mitral stenosis is oversimplified when merely resolved to a discussion of regurgitation versus stenosis.

It has been found that (1) the heart must not be dislocated from the position of optimum function; (2) the direct surgery of the mitral valve is more readily accomplished by approaching the valve from above, through the auricle; (3) certain types of stenosis are better tolerated than others; (4) the heart rate alters the severity of the given lesions.

On the basis of these facts, different types of surgical procedures have been devised for different clinical and pathologic categories of patients:

1. Patients in whom the mechanical obstruction due to the stenotic valve is the outstanding feature. In these patients, cardiac output is low and does not go up with exercise. It seems logical to treat these by *valvuloplasty,* that is, enlarging the mitral orifice by cutting away the commissures. This allows some possible return of function with a minimum burden of added regurgitation.
2. Patients who suffer from marked mitral regurgitation. The clinical symptoms here are predominantly due to pulmonary hypertension, with the aggravating effect of tachycardia causing frequent episodes of pulmonary edema (or, as we term it, pulmonary decompensation). These patients have a normal cardiac output that can increase with exercise. *Interatrial septal defects* have been created in 2 patients to decompress the left auricle and pulmonic bed during periods of stress.
3. Patients so debilitated that they cannot be considered for direct cardiac manipulation and those who have episodes of tachycardia that produce pulmonary edema (pulmonary decompensation). Here, *cervicodorsal sympathectomy* may maintain a slower pulse rate and also eliminate various cardiopulmonary reflexes that may play a part in the production of pulmonary edema.

A plea is made that patients be selected and evaluated before and after operation by critical, objective methods, including cardiac catheterization.

This report comprehends a study group of 20 patients, to date, of whom 5 have been treated surgically. There has been 1 surgical death.

5. SURGERY OF MITRAL STENOSIS. Charles P. Bailey, M.D., F.A.C.S., and (by invitation) Robert P. Glover, M.D., M.Sc., and Thomas J. E. O'Neill, M.D., Philadelphia, Pa.

A. Historical Review

B. Modern concept of pathology and possibilities of altering the changes. This embraces the various shunt operations: (1) azygos vein-pulmonary vein anastomosis, (2) per-formation of the interauricular septum, and (3) production of a tricuspid regurgitation. It also considers the various operations upon the mitral valve: (1) simple dilatation, (2) cutting across the valve cusps, (3) excision of a portion of the valve ring (simple), and (4) directed excision of the valve (valvuloplasty) and (5) commissurotomy under direct digital control.

Presented are 10 cases of commissurotomy for mitral stenosis, 1 case of digital dilatation of the valve, and 1 case of opening of the interauricular septum. Discussion of failures and successes will be directed toward better selection for surgery and better technique and management.

6. COMPLETE FAILURE OF STERNAL FUSION WITH HERNIATION OF PERICARDIUM. HERBERT C. MAIER, M.D., NEW YORK, N. Y., AND FRANK BORTONE, M.D., Jersey City, N. J.

A case of complete lack of fusion of the entire length of the sternum with herniation of the pericardium is reported. The congenital defect was successfully corrected by surgery in infancy. The importance of performing the operation very shortly after birth is well illustrated by our case.

The embryologic development of the sternum is reviewed briefly. The relationship of cleft sternum and ectopia cordis is discussed.

Due to the lack of rigid thoracic cage at the site of the sternal defect, considerable paradoxical motion may occur with resultant respiratory and cardiocirculatory difficulty. If only a partial cleft sternum or a narrow sternal fissure is present, symptoms may be absent.

7. ANGIOCARDIOGRAPHY AND AORTOGRAPHY IN THE DIAGNOSIS OF CONGENITAL CARDIOVASCULAR LESIONS. THOMAS H. BURFORD, M.D., and (by invitation) MERL J. CARSON, M.D., AND WENDELL G. SCOTT, M.D., St. Louis, Mo.

With the development of the tautography by one of our group (W. G. S.), the technique of cardiovascular visualization has become an invaluable and extremely accurate method of diagnosis in congenital lesions of the heart and great vessels. The intravenous injection of Diodrast by this technique serves admirably to elucidate the type of deformity present in the heart. Retroarterial injection has proved equally valuable in clarifying anomalies of the aorta and its immediate branches.

The valuable procedure of cardiac catheterization is limited in application. The very young subjects in whom diagnostic difficulties are most commonly encountered have not been suitable subjects for catheterization in our experience. It is in this group that visualization is of the greatest value.

The procedure is of further value in that it affords accurate, preoperative evidence of operability or inoperability in certain lesions, particularly coarctation of the aorta.

A relatively large experience is reviewed, with a description of the techniques and an appraisal of the results. (Lantern slides and a 5 minute colored movie.)

8. THE ROLE OF ANGIOCARDIOGRAPHY AND VENOGRAPHY IN MEDIASTINAL AND PARAMEDIASTINAL LESIONS. OSLER A. ABBOTT, M.D., and (by invitation) TED F. LEIGH, M.D., and WILLIAM A. HOPKINS, M.D., Atlanta, Ga.

This presentation discusses the role which may be played by the use of Diodrast visualization in evaluating mediastinal and paramediastinal tumors. The use of the angiocardiogram constitutes the main point of discussion, but the role of Diodrast visualization of the innominate veins and superior vena cava is also discussed. The value of this technique in lesions of vascular origin is easily appreciated. Its value in nonvascular lesions is also stressed.

Unusual cases are presented, which emphasize the need for this method of investigation in the majority of mediastinal lesions. A case of congenital massive aneurysm of the superior vena cava is included in the presentation, and the successful method of operative correction presented. The importance of angiocardiography in different projections is also considered.

9. RESPIRATORY ACIDOSIS DURING THORACIC SURGERY. Henry K. Beecher, M.D., and Anna J. Murphy, B.S. (by invitation), Boston, Mass.

Abnormality in the blood gases (too low oxygen, too high carbon dioxide) is a common cause of disaster during thoracic surgery. Procedures in anesthesia must be designed to preserve these gases within normal limits. Our anesthesia practices are given with studies of the arterial blood in some 40 patients during transpleural thoracic surgery.

10. BLOOD VOLUME CHANGES IN TUBERCULOUS PATIENTS TREATED BY THORACOPLASTY. Frank F. Allbritten, Jr., M.D., and (by invitation) Herbert Lipshutz, M.D., Bernard J. Miller, M.D., and John H. Gibbon, Jr., M.D., Philadelphia, Pa.

A rising pulse rate and falling blood pressure have occasionally required the discontinuance of a stage of thoracoplasty in patients with pulmonary tuberculosis. This occurs more commonly in patients with far-advanced bilateral disease and in the second and third stages of thoracoplasty. Although blood lost at operation was adequately replaced it occurred to us that an unrecognized diminution in circulating blood volume could account for these symptoms. It was conceivable that these chronically ill patients had a diminished blood volume on admission to the hospital and that there was an additional unrecognized blood loss into the operative wound between stages. The following study was made in order to obtain pertinent data.

Observations were made on 10 patients with pulmonary tuberculosis treated by thoracoplasty. All had seven-rib thoracoplasties. The plasma volume was determined by the method of Gibson and Evelyn. The blood volume was calculated from this figure and the hematocrit. The blood lost during each stage of thoracoplasty was measured by weighing sponges before and after use, and this estimation was compared with the difference in circulating blood volume before and after operation. The blood lost between the stages of thoracoplasty was taken as the difference between the blood volume at the completion of one stage and the blood volume immediately preceding the next stage.

With one exception, all patients in this series had a diminished blood volume prior to thoracoplasty, computing normal volume from surface area by the method of Gibson and Evans.

The operative blood loss during the first stage was found to be almost twice as much as that occurring at the second and third stages; averaging 832 c.c. in the first stage, and 480 c.c. and 397 c.c. in the second and third stages, respectively.

A significant decrease in the circulating blood volume was found to occur in the interval between stages. Between the first and second stages the decrease in blood volume averaged 428 c.c. and between the second and third stages it averaged 445 c.c. Some of the decrease in blood volume between stages has been attributed to the extravasation of serosanguineous fluid into the large wound space which is created after the upper three to five ribs are resected. With the completion of a seven-rib thoracoplasty, the scapula drops in to obliterate this space.

Patients with arrested disease following thoracoplasty regained and maintained a normal circulating blood volume.

These measurements indicate the advisability of restoring a normal circulating blood volume preceding a surgical procedure in patients with pulmonary tuberculosis, as well as adequate replacement of blood during operation and between stages of a thoracoplasty.

11. PULMONARY CIRCULATION AND ALVEOLAR VENTILATION—PERFUSION RELATIONSHIPS AFTER PNEUMONECTOMY. A COURNAND, M.D., and (by invitation) R. L. RILEY, M.D., A. HIMMELSTEIN, M.D., and R. AUSTRIAN, M.D., New York, N. Y.

Fourteen patients ranging in age from 14 to 72 years were studied after pneumonectomy. The time since pneumonectomy was less than seven months in 6 cases and from two to eleven years in the remaining 8 cases. The preoperative diagnoses included chronic pulmonary suppuration, tuberculous bronchial stenosis, and carcinoma of the bronchus.

The pulmonary blood flow and pulmonary arterial pressure were measured at rest in 8 cases and following exercise in 4 cases, using the technique of cardiac catheterization. The correlation between ventilation and perfusion was studied in all 14 cases by recently developed techniques which involved the determination of pCO2 and pO2 in the arterial blood and the calculation of alveolar gas tensions. On the basis of these measurements it is possible to estimate the proportion of mixed venous blood which fails to pass through normally ventilated alveoli and to estimate the proportion of inspired air which fails to reach normally perfused alveoli. In all cases the studies were supplemented by the measurement of lung volumes, maximum breathing capacity, ventilation, and gas exchange as previously reported.

Although the dynamics of the pulmonary circulation at rest were but slightly altered even in cases studied several years after pulmonary resection, there was invariably a significant degree of pulmonary arterial hypertension during moderate exercise. This finding is in contrast with observations in normal individuals during much more severe exercise (Am. J. Physiol. 152: 372, 1948). Since the blood flow through the remaining lung during moderate exercise exceeded the flow through each lung of normal individuals during severe exercise, it cannot be stated whether the rise in pulmonary arterial pressure was due to pathologic changes in the pulmonary vascular system or to the inability of the normal vascular bed of one lung to accommodate an unusually large blood flow. The relationships between alveolar ventilation and alveolar perfusion were normal in 6 cases. In the remaining 8 there was evidence of perfusion of poorly ventilated areas and/or ventilation of poorly perfused areas. There was no consistent correlation between these changes and (a) the type of disease prior to pneumonectomy, and (b) the presence or absence of a thoracoplasty. In the older age group moderate emphysema invariably developed with evidence of ventilation of poorly perfused areas.

12. THE SURGICAL MANAGEMENT OF CHRONIC "SPONTANEOUS" PNEUMOTHORAX. LYMAN A. BREWER, III, M.D., FRANK S. DOLLEY, M.D., and (by invitation) BYRON H. EVANS, M.D., Los Angeles, Calif.

A series of cases of chronic and recurring "spontaneous" pneumothorax is presented. "Symptomatic" pneumothorax occurring with well-established pulmonary disease secondary to trauma, pulmonary abscess, infarct, tuberculosis, and lung tumors has been excluded. Although there is a great controversy concerning the etiology of "spontaneous" pneumothorax, from the practical point of view we recognize three main conditions as causing the vast majority of these cases: (1) congenital cysts, occurring most often in infants and children; (2) pulmonary vesicles, secondary to localized subpleural pulmonary and bronchiolar scars occurring in young adults; and (3) blebs or bullae of emphysema found in middle-aged or older persons suffering from a more generalized form of pulmonary emphysema. Most cases of acute "spontaneous" pneumothorax can be successfully treated by conservative methods, which include bed rest, oxygen, and the adjustment of the intrapleural pressures to allow for the sealing off of the pulmonary aperture and the gradual expansion of the lung.

Chronic "spontaneous" pneumothorax presents a more difficult therapeutic problem. Surgical methods are indicated because conservative measures have failed. With surgery, maximum pulmonary function is restored and chronic invalidism prevented.

The causes of the persistence of the pneumothorax are sometimes difficult to demonstrate. Most often, however, the etiologic factor is one of three main conditions: (1) intrapleural adhesions, which exert a "guy wire" effect on the lung, holding it on a tension so that the lung cannot collapse sufficiently to allow the pulmonary opening to close; (2) fibrosis about the opening in the lung or a congenital lesion lined by bronchial epithelium; (3) the formation of a pleural membrane as the result of the organization of fibrin deposits secondary to a pleural effusion. Because of the nature of the pathologic processes, we believe that the introduction of irritating substances into the pleural cavity to produce a violent pleuritis is contraindicated. The surgical measures we have employed include: (1) closed catheter pleural drainage; (2) phrenic paralysis; (3) thoracoscopy with internal pneumonolysis; and (4) open thoracotomy. Open thoracotomy permits the most complete and definitive attack to the problem, for at this operation four essential techniques may be employed: (1) complete pneumonolysis; (2) surgical closure of the pulmonary opening; (3) resection of pulmonary cyst or bleb regardless of the type; (4) decortication of the collapsed lung. This subject has received little attention in medical literature. The authors wished to present their experience with the surgical management of 15 cases. The indications and results of the various surgical techniques are discussed and evaluated.

13. SEGMENTAL RESECTION IN PULMONARY DISEASES. J. MAXWELL CHAMBERLAIN, M.D., New York, N. Y., and (by invitation) COMMANDER THOMAS C. RYAN, U.S.N.

One hundred segmental resections were done for tuberculous (25 per cent) and nontuberculous (75 per cent) pulmonary lesions. The standard technique first suggested by Churchill was used in the majority of cases. The bronchus serving the diseased segment is defined and divided. Gentle traction on the bronchus soon discloses the companion vessels and the artery is ligated first. Only the tributaries to the vein are ligated, however, since it has been pointed out that the veins serve adjacent segments.

The indications for segmental resection in bronchiectasis are well known, but segmental resection in acute putrid lung abscess is usually contraindicated. However, after chemotherapy or surgical drainage of a lung abscess, a state of indolent chronicity may be reached and in such cases segmental resection becomes a sound surgical solution. The indications for segmental resection in tuberculosis are not well established, but it would seem that the small, discrete, isolated focus such as a tuberculoma or a small thick-walled inspissated cavity are the two types of lesion most vulnerable to resection of a segment.

In comparison with the removal of a lobe, the operating time and complications are moderately increased. Further, the postoperative care is more complicated and demands great vigilance. The results, however, seem to justify the continued use of this procedure. Although when only one segment of a lobe remains and this segment is a *small* one, a lobectomy may be the procedure of choice.

The various methods of segmental resection will be discussed and typical cases with bronchospirometric studies will be presented.

14. RESECTION OF PULMONARY SEGMENTS—DETAILS OF TECHNIQUE AND RECENT RESULTS. RICHARD H. OVERHOLT, M.D., FRANCIS M. WOODS, M.D., and (by invitation) BEATTY H. RAMSAY, M.D., Brookline, Mass.

The operative procedure of segmental resection of the lungs has now matured. Nearly all the technical difficulties have yielded to improvements in technique until now it can be demonstrated that empyema, bronchopleural fistula, and difficulty with re-expansion of the remaining lung are uncommon and unexpected complications. It is our purpose to record the difficulties that have been encountered and to show how each may be best avoided. Detailed technical steps of the operation will be illustrated. Brief reference will be made to the use of segmental resection in pulmonary malignancy and tuberculosis. Finally, a report will be given on the postoperative course in all the segmental resections carried out during the past six months, during which time technical maneuvers and management have remained unchanged.

15. BRONCHOLITHIASIS. HERBERT W. SCHMIDT, M.D. (by invitation), O. THERON CLAGETT, M.D., AND JOHN R. MCDONALD, M.D., Rochester, Minn.

The subject of broncholithiasis has been of interest to the medical profession for centuries. It has been said that the subject interested Aristotle some three hundred years B.C. In spite of this fact, we could find only 78 cases reported in the English medical literature up to 1948.

We should like to report 42 cases of broncholithiasis in our experience. In 14 of these cases, the broncholith was removed at the time of bronchoscopy. In 3, it was impossible to remove the stone at the time of endoscopic examination but the involved bronchus was dilated and the stone was coughed up immediately following the examination. Ten patients had pulmonary resections for indeterminate lesions which were proved to be due to broncholiths. The rest of the patients in this series had the history of having coughed up single or multiple stones. The clinical, bronchoscopic, pathologic, and surgical aspects of broncholithiasis are discussed.

Broncholiths will be diagnosed with increasing frequency at the time of exploratory thoracotomy performed because of indeterminate pulmonary lesions. In this group it will usually be necessary to carry out a resection of a portion of the lung because primary bronchiogenic carcinoma in most instances cannot be excluded. Because of the pathology involved, we believe that as small an amount of lung tissue as possible should be resected at the time of surgery.

16. THE RESULTS OF SURGERY IN BRONCHIECTASIS. ADRIAN LAMBERT, M.D., New York, N. Y.

The series representing an analysis of 100 consecutive operations on 103 patients for bronchiectasis, with and without acute suppurative disease, and involving one or two lobes and an entire lung, is offered from the Chest Division of Bellevue Hospital during the years 1939 to 1945. Cases in which tuberculosis was demonstrated in the specimen removed have been omitted from this series. Similarly, cases in which the primary disease process was a lung abscess have not been included. The mortality in bronchiectasis with and without suppuration in one or two lobes and involving an entire lung is analyzed. The postoperative complications have been related to the operative technique and to the existing pathology in the specimen removed and the incidence of sputum related to the mortality in the four groups. The results include a follow-up of 78 of the 91 survivals that were followed over an average period of four years. These have been classified according to the original pathology at the time of operation, according to associated sinus disease and bronchiectasis, and according to postoperative residual stumps and the development of tuberculosis.

17. THE SURGICAL TREATMENT OF BILATERAL BRONCHIECTASIS. FREDERICK G. KERGIN, M.D., Toronto, Canada.

Fifty-eight patients have been treated surgically for bilateral bronchiectasis at the Toronto General Hospital and Hospital for Sick Children, Toronto. Of these, 27 have had unilateral operations and 31 have had staged bilateral resections.

This group of patients has been subjected to 94 excision operations with 4 deaths, all following the second side of a bilateral resection. By attention to certain technical details, which are described, it has been possible to reduce the hazards of treatment. The last 18 consecutive bilateral resections have been completed without mortality.

The results of treatment in relation to relief of symptoms and effect on exercise tolerance are discussed. Eighty-three per cent of the patients who have had bilateral resection are symptom free and the remainder improved.

In this series partial lower lobectomy with preservation of the superior segment was done 13 times. The results of this procedure are described.

ADDRESS OF THE PRESIDENT—EDWARD D. CHURCHILL, M.D., BOSTON, MASS.

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18. MEDIASTINAL "TUBERCULOMA"—SURGICAL REMOVAL IN FOUR PATIENTS.

PAUL C. SAMSON, M.D., AND (by invitation) BRIGADIER GENERAL LEONARD HEATON, U.S.A., AND DAVID J. DUGAN, M.D., Oakland, Calif.

The scarcity of information in the literature concerning tuberculomas of the mediastinum prompts this report. Four patients have been subjected to surgery. The correct diagnosis was unsuspected in all prior to exploration. Various preoperative diagnoses were entertained: dermoid tumor; bronchiogenic cyst; intrapulmonary cyst; aneurysm. One patient was asymptomatic. In the others, symptoms ranged from vague thoracic discomfort to severe cough and dyspnea because of partial tracheal obstruction.

The tuberculin test was repeatedly negative in one patient and was positive only in 1-100 dilution in another. Tubercle bacilli were not recovered from any of the specimens. Pathologically, there were caseation, epithelioid tissue, and multinucleated giant cells.

The discussion will include consideration of certain problems. (1) Are these "tumors" always due to tuberculous infection or may other organisms cause the pathologic picture? (2) What steps may be taken preoperatively to establish more certainly a diagnosis of "Tuberculoma"? (3) When exploratory operation in a patient without symptoms reveals a caseogranulomatous mass, should it be removed?

19. PNEUMONECTOMY FOLLOWED BY IMMEDIATE THORACOPLASTY.

(By invitation) ROLAND K. IVERSON, M.D., AND H. L. SKINNER, M.D., NEW YORK, N. Y.

Pulmonary resection is rapidly assuming its proper place in the treatment of pulmonary tuberculosis. Amazing progress has been made in this field of surgery but certain complications arise from time to time which happens in any new, radical procedure. In order to circumvent these complications it has become routine practice in most thoracic clinics to follow pneumonectomy by one or two stages of thoracoplasty.

It is our opinion that it is still better to do a thoracoplasty immediately following pneumonectomy in certain selected cases. In doing the thoracoplasty the transverse processes and posterior rib stumps are not resected. The first rib is left in place and occasionally the second is left in place. We have been particularly impressed with the benign postoperative course. (Report of cases with lantern slides demonstration.) The procedure has the following advantages:

1. Necessity of only one operation
2. Prompt obliteration of pleural cavity to lessen the danger of bronchial fistula and empyema
3. Avoidance of mediastinal displacements
4. A more effective coughing mechanism present in the immediate postoperative period

20. FUNNEL CHEST AND ALLIED THORACIC CAGE DEFORMITIES.

CHARLES W. LESTER, M.D., NEW YORK, N. Y.

A congenital shortening of the anteroposterior measurements of the diaphragm commonly produces a funnel chest deformity but may also produce other deformities of the thoracic cage associated with the funnel deformity or existing separately. These allied deformities consist, for the most part, of abnormal depressions, either unilateral or transverse, or abnormal protrusions of one or more ribs. During the past five years numerous thoracic cage deformities of diaphragmatic origin have been observed and 27 have been operated upon. Modifications of the procedures described by Brown have been employed for the funnel deformities. The others have required individualized operations. This experience has produced certain concepts regarding etiology, selection of cases for surgery, optimum age for operation, type of operation to be employed, complications, and results. These are discussed.

21. AN EXPERIMENTAL STUDY OF THE BLOOD SUPPLY OF THE ESOPHAGUS AND ITS RELATION TO ESOPHAGEAL RESECTION AND ANASTOMOSIS.

John Skek, M.D. (by invitation), Carlos Prietta (by invitation), Wm. M. Tuttle, M.D., and E. J. O'Brien, M.D., Detroit, Mich.

The esophagus of dogs was mobilized from the mediastinum and portions were resected. The cut ends were then anastomosed by using interrupted sutures of fine silk in two layers. It was likewise possible to remove the esophagus from behind the aorta and anastomose it in front of the aorta.

These experiments were carried out with much of the blood supply to the esophagus ligated. In spite of this healing occurred regularly.

Injection studies were made of the esophageal blood supply under various conditions, and it becomes evident that the supply is much better than has been generally thought.

22. THE TREATMENT OF SHORT ESOPHAGEAL STRICTURES BY RESECTION AND END-TO-END ANASTOMOSIS.

William M. Tuttle, M.D., and J. C. Day, M.D., Detroit, Mich.

It has long been thought that end-to-end anastomosis of the esophagus was not a safe or feasible procedure.

Within the past two years 6 patients, ranging in age from 1 to 70 years, with short esophageal strictures have been treated by resection of the stricture either completely or by a wedging type of resection and the normal ends reunited by interrupted sutures in two layers.

There has been a good functional result in each patient. In no instance has the anastomosis leaked.

23. ACQUIRED NONMALIGNANT ESOPHAGOTRACHEOBRONCHIAL FISTULAS.

Frank Philip Coleman, M.D., and George H. Bunch, Jr., M.D. (by invitation), Richmond, Va.

Malignant lesions account for the majority of acquired communications between the esophagus and tracheobronchial tree. The nonmalignant fistula may be caused by trauma, tuberculosis, syphilis, esophageal diverticula, and pyogenic and fungus infections. Frequently, the underlying pathologic process cannot be ascertained at the time of operative closure of the fistula. The hopeless prognosis of bronchiogenic and esophageal cancer associated with esophagotracheobronchial fistulas and the infrequency of acquired nonmalignant communications between the esophagus and tracheobronchial tree have resulted in the accumulation of meager experience in managing this distressing complication of trauma and infection. To the 7 case reports in the English literature of operative closure of esophagorespiratory fistulas, the authors have added 4 successful cases. The clinical features, preoperative care, problems of anesthesia, and surgical technique are emphasized. (Motion picture illustrating surgical technique.)

24. THE COMBINED ABDOMINAL AND RIGHT THORACIC APPROACH TO LESIONS OF THE MIDDLE AND UPPER THIRD OF THE ESOPHAGUS.

Edward M. Kent, M.D. and Samuel P. Harbison (by invitation), Pittsburgh, Pa.

Following Ivor Lewis' lead, a traumatic stricture of the upper two-thirds of the esophagus was successfully treated by resection and esophagogastrostomy through the right thorax in August, 1947. The ease with which the entire esophagus to the top of the thorax may be resected by this approach logically led to the development of the method for malignant disease. The operation is necessarily done in two stages, performed one week apart or at the same time. The abdomen is opened first and exploration carried out. If no metastases are present, the stomach is carefully divested of its entire blood supply save for the right gastric and right gastroepiploic arteries. Dissection is carried to the esophagus itself and one inch or more of this organ is freed up. In markedly debilitated patients who have complete obstruction, a jejunostomy may be established before closing the abdomen.

At the second stage the right thorax is entered posterolaterally by resection of a suitable rib. If operable, the lesion is mobilized widely after ligation of the azygos vein. The stomach is then delivered after enlarging the esophageal hiatus, resection is carried out, and an esophagogastrostomy accomplished. The principal advantage of the right approach lies in the absence of the aortic arch on this side; dissection does not have to be performed beneath it; and the resulting anastomosis, whether above or just below the arch, is not angulated as is the case on the left. Details and pitfalls of the method are described. It is believed that a better salvage of patients with esophageal malignancies will be obtained by this more direct approach to the lesion.

25. FURTHER OBSERVATIONS ON PACKING OF MEDIASTINUM FOR ESOPHAGEAL VARICES. JOHN H. GARLOCK, M.D., AND MAX SOM, M.D. (by invitation), New York, N. Y.

The authors submit a supplementary report on the original paper published in the *Journal of the American Medical Association* for Nov. 8, 1947, at which time they reported 2 cases accorded this therapy. The idea is based on the supposition that by establishing a large area of granulation tissue external to the muscular layer of the esophagus at a distance removed from the seat of the varices there will develop a collateral circulation which will be outside of the esophagus, thereby taking the load off the venous pressure in the esophageal varices which lie in a submucosal position. On the basis of an experience with 10 cases there would seem considerable justification for this procedure before the surgeon should consider the more extensive and more dangerous operation of portacaval shunt or splenorenal vein anastomosis. The authors will report in detail the history of 10 patients, the longest follow-up being seven years.

26. PULMONARY ALVEOLAR ADENOMATOSIS. H. BRODIE STEPHENS, M.D., AND SIDNEY J. SHIPMEN, M.D., San Francisco, Calif.

Pulmonary alveolar adenomatosis, or jagziekte disease, has awakened increasing medical interest as the condition has been recognized in human beings. Long recognized as an endemic disease of sheep it has now been found to affect human beings more and more frequently. Nevertheless, until 1947, only 12 authentic cases were on record, only one of which was diagnosed prior to death, the case of Pierson, Holman and Wood, in which the diagnosis was made at operation.

In the case reported herewith it was possible to make the diagnosis before surgery, to confirm it by lobectomy, and to bring about apparent cure.

27. PLASTIC RECONSTRUCTION OF TUBERCULOUS BRONCHOSTENOSIS WITH DERMAL GRAFTS. PAUL W. GEBAUER, M.D., Honolulu, Hawaii.

28. PULMONARY RESECTION OF METASTATIC MALIGNANCY. HAWLEY H. SEILER (by invitation), O. THERON CLAGETT, M.D., AND JOHN R. McDONALD, M.D., Oteen, N. C.

29. BRONCHOGENIC CARCINOMA—PART I. A PATHOLOGICAL CLINICAL STUDY OF FULL-SIZE MOUNTS FROM OPERATED CARCINOMA. F. J. PHILLIPS, M.D., AND (by invitation) CLAIR E. BASINGER, M.D., AND W. E. ADAMS, M.D., Chicago, Ill.

BRONCHOGENIC CARCINOMA—PART II. THE CORRELATION OF PATHOLOGIC CHARACTERISTICS AND CLINICAL MANIFESTATION IN UNRESECTABLE AND UNEXPLORED POST-MORTEM LUNG TUMORS.

GEORGE M. BOGARDUS, M.D. (by invitation), W. E. ADAMS, M.D., AND F. J. PHILLIPS, M.D., Chicago, Ill.

The controversy among clinicians and pathologists regarding the pathogenesis of primary carcinoma of the lung stimulated us to make and study full-sized mounts of representative cross sections of all tumors of the lung removed. An attempt was made to correlate the type of tumor, the site of the tumor, and the size of the tumor with the clinical manifestations as demonstrated by history, physical and radiologic and bronchoscopic examinations, and findings at exploration. The cell type has been studied in its relationship to the site and size of the tumor, the rate of growth, the extension into contiguous tissues, and metastases to other organs. Of the 40 cases thus studied, 27 were found to be of squamous cell type with or without pearl formation and 13 exhibited both epidermoid and adenocarcinoma.

A similar study was made of 36 nonresectable tumors and 36 unexplored cases in which tumors were found at autopsy. Of the nonresectable group, approximately one-half were of an undifferentiated cell type. The other one-half were of a nonkeratinizing squamous cell variety. Of the tumors studied from autopsy specimen, 15 were adenocarcinoma, 14 were undifferentiated cell, 6 were epidermoid, and 1 was a mixture of adeno- and squamous cell carcinoma. Illustrations of these factors are presented and their significance discussed.

30. THE MANAGEMENT OF CHYLOTHORAX.

RICHARD H. MEADE, JR., M.D., JEROME R. HEAD, M.D., AND CHESTER W. MOEN, M.D. (by invitation), Grand Rapids, Mich.

Although chylothorax is often associated with an incurable disease, or with severe injury, it may occur as a result of mild trauma. In most instances, untreated chylothorax results in death. Experimental work and clinical experience have proved that the thoracic duct can be safely ligated. Anatomic studies show that there is a wide variation in its gross structure, and that there may be only one duct, or there may be a number of minute ones. Chylothorax can be cured by ligation of the thoracic duct, but it may also be controlled at times by repeated aspirations, or by suction drainage. A general discussion of the anatomy of the duct, and of the physiologic effects of its ligation will be given. Three cases will be reported illustrating different etiological factors, and different, successful methods of treatment. Chylothorax should rarely be fatal if recognized in time and properly treated.

31. THE SURGICAL TREATMENT OF ROUND TUBERCULOUS LESIONS (TUBERCULOMATA).

COLONEL HUGH W. MAHON, M.C. (by invitation), AND COLONEL JAMES H. FORSEE, M.C., Denver, Colo.

This paper deals with a group of 35 patients treated by pulmonary resection, either lobectomy or wedge-shaped excision, for so-called tuberculomata at Fitzsimons General Hospital. The clinical *manifestations were generally characterized by minimal symptomatology* and the solid-like found shaped lesion was often detected by routine x-ray examination of the chest. The similarity to other lesions, in particular coccidioidomycosis and neoplasms, is discussed. In approximately 80 per cent, exploratory thoracotomy was necessary as an aid in diagnosis but a positive diagnosis was not established until histopathologic and bacteriologic examinations were completed. The pathology of this lesion is discussed in detail including a correlation of the radiologic appearance with the gross and microscopic pathology. The hazards of considering this lesion as benign or arrested tuberculosis are emphasized. Our policy of management after operation has been largely determined by bacteriologic and histopathologic findings. Those patients in whom tubercle bacilli were demonstrated were advised to follow a period of hospital management of six to twelve months or longer. Those patients in whom tubercle bacilli were not demonstrated in the tuberculoma and in whom daughter tubercles were absent and who had no other lung pathology were returned to military duty or to their normal activities in approximately three months after operation. A follow-up study of these patients is presented.

32. TRANSTHORACIC THYROIDECTOMY. Herbert D. Adams, M.D., Boston, Mass.

Intrathoracic goiter may be defined as goiter in which the goitrous mass lies in the mediastinum entirely below the level of the superior thoracic strait. At the Lahey Clinic nearly 28,000 patients with goiter have been operated on and hundreds of these goiters have been classified as being truly intrathoracic by these criteria. Practically all of these, many of tremendous size, have been removed satisfactorily by the cervical route. This has been technically possible chiefly by a maneuver described by Lahey of evacuation of the necrotic and colloid central portions of these masses, thereby permitting the capsular portions to be delivered from the mediastinum. This has been technically feasible and satisfactory in by far the majority of cases. However, there have been three cases in which the intrathoracic goiter has been removed by the transthoracic route. Two patients were operated on transpleurally because of inability to differentiate by roentgenologic and other studies the mediastinal shadow from other types of mediastinal tumors, and because of their extremely low position in the mediastinum. This differential diagnosis is discussed fully. The third case was done transpleurally because an attempt had been made elsewhere to remove the goiter through the neck, with failure due to the extreme vascularity and size of this goiter. The surgical management and technical aspects of transthoracic thyroidectomy are presented.

The American Association for Thoracic Surgery

1949-1950

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REPORT OF MEETING OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

MARCH 29, 30, AND 31, 1949

THE twenty-ninth meeting of the American Association for Thoracic Surgery was held in New Orleans, La., at the Hotel Roosevelt, on March 29, 30, and 31, 1949.

The following recommendations of the Membership Committee were accepted by the Association:

Honorary membership was conferred upon Dr. Carl Semb, Oslo, Norway.

The following active members were retired, at their own request, to Senior membership:

Dr. Richard H. Diffenbach, Newark, N. J.
Dr. Frank S. Johns, Richmond, Va.

The following Associate members were elected to Active membership:

Dr. William W. Buckingham, Kansas City, Mo.
Dr. Osler Abbott, Atlanta, Ga.
Dr. Conrad R. Lam, Detroit, Mich.
Dr. James D. Murphy, Oteen, N. C.
Dr. Paul W. Sanger, Charlotte, N. C.
Dr. Marion Lawrence White, Jr., Charlottesville, Va.
Dr. Frank F. Allbritten, Jr., Philadelphia, Pa.
Dr. Rollins Hanlon, Baltimore, Md.
Dr. Willis J. Potts, Chicago, Ill.

The following candidates were elected to Associate membership:

Dr. Edward James Beattie, Jr., George Washington University School of Medicine, Washington, D. C.

Dr. James Carswell, Jr., Veterans Administration Hospital, McKinney, Texas
Dr. Roy Barnett Cohn, 2347 Laguna Street, San Francisco, Calif.
Dr. Charles Francis Chunn, 442 W. Lafayette Street, Tampa 6, Fla.
Dr. Anthony Daniel Crecca, 376 Roseville Avenue, Newark 7, N. J.
Dr. Paul Trumbull DeCamp, 1835 General Pershing, New Orleans, La.
Dr. Donald Brian Effler, Euclid and E. 93rd Street, Cleveland 6, Ohio
Dr. Byron Henry Evans, 1930 Wilshire Blvd., Suite 1400, Los Angeles, Calif.
Dr. Edouard Donat Gagnon, 3411 St. Denis Street, Montreal, Que.
Dr. Robert Prentice Glover, 2107 Spruce Street, Philadelphia, Pa.
Dr. Aaron Himmelstein, 70 East 96th Street, New York 28, N. Y.
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Dr. Charles Keeling Kirby, 3400 Spruce Street, Philadelphia, Pa.
Dr. Phillip John Kunderman, 165 Livingston Avenue, New Brunswick, N. J.
Dr. William Morris Lees, 812 Hutchins Avenue, Ann Arbor, Mich.
Dr. Saul Allen Mackler, 104 S. Michigan Avenue, Chicago 3, Ill.
Dr. Joseph Macmanus, 491 Delaware, Buffalo 2, N. Y.
Dr. John Henry Mayer, Jr., 829 West 55th Street, Kansas City, Mo.
Dr. Elliott Michelson, Veterans Hospital, Sunmount, N. Y.
Dr. Carrol Cameron Miller, 205 Beacon Street, Boston 15, Mass.
Dr. Roland Davis Pinkham, 1106 Cobb Building, Seattle, Wash.
Dr. Victor Richards, Stanford-Lane Hospital, San Francisco 15, Calif.
Dr. Herbert W. Schmidt, Mayo Clinic, Rochester, Minn.
Dr. Gabriel Parkust Seley, 39 East 61st Street, New York 21, N. Y.
Dr. William Dempsey Seybold, Mayo Clinic, Rochester, Minn.
Dr. Harris B. Shumacker, Jr., Indiana University Medical Center, Indianapolis 7, Ind.
Dr. Lamar Soutter, 205 Beacon Street, Boston, Mass.
Dr. Allan Stranahan, Albany Hospital, Albany, N. Y.
Dr. Henry Swan, II, 410 Marion Street, Denver, Colo.
Dr. Wilson Weisel, 324 East Wisconsin Avenue, Milwaukee 2, Wis.
Dr. George Wilbur Wright, 103 Park Avenue, Saranac Lake, N. Y.

NOTICE

The thirtieth annual meeting of the American Association for Thoracic Surgery will be held April 15, 16, 17, and 18, 1950, in Denver, Colo., Headquarters will be at the Cosmopolitan Hotel.

Requests for hotel reservations should be mailed direct to Col. James H. Forsee, 519 17th Street, Denver, Colo.

Abstracts for presentation of papers for the 1950 meetings must be received for consideration by the Program Committee on or before January 1, 1950. These abstracts should be submitted in *quadruplicate* and addressed to the Secretary of the Association, Dr. Brian Blades, George Washington University Hospital, 901 23rd Street, N. W., Washington 7, D. C. *They should not be sent to the Editor.* Abstracts received after January 1, 1950, will not be considered.

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Original Communications

CLINICAL EXPERIENCES WITH THE APPLICATION OF POLYTHENE CELLOPHANE UPON ANEURYSMS OF THE THORACIC VESSELS

Osler A. Abbott, M.D.
Atlanta, Ga.

It IS important to stress at the outset that this paper deals essentially with the experiences obtained in applying Polythene cellophane to aneurysms of the human intrathoracic vessels. It is far too early in the period of observation which has been allowed to come to any definite conclusions. This paper must be considered in the form of a preliminary report. In view of certain rather dramatic findings noted upon the experimental application of cellophane upon the vessels of animals, I felt that one was justified in applying this method to a fairly large group of human patients who present themselves with a disease which entails such a serious prognosis as a large aneurysm of an intrathoracic vessel. The application of this material to the human aorta is certainly not an original procedure, but this communication will report the application of this material to portions of certain vessels which have not previously been so dealt with, and describes a larger group of patients so treated than elsewhere reported.

It is important for us to refresh our memories in regard to the clinical history of an aortic aneurysm. The life expectancy of a patient with an aneurysm of the aorta is an extremely variable matter, ranging from the patient in whom a fatal result occurs in a period of less than six months after the first x-ray evidence of aneurysmal disease is obtained to the other extreme of the patient in whom an aneurysm may be observed to be present over a period of from ten to twenty years.

Aneurysms of the thoracic vessels may differ greatly in their etiology. Aneurysms with the same etiology may vary greatly in their life expectancy. These considerations, therefore, make one realize that only a study of a very large group of patients having aneurysmal disease from all known causes, and followed over a period of many years, can allow us to make any definitive conclusions.

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There is no doubt that the final method of control of aneurysmal disease is the prevention of its cause. However, it does seem reasonable to consider that once an aneurysm has been produced, there is a permanent structural defect, which will need structural correction. The direct approach upon a structural defect, so as to re-mold a facsimile of the normal, is the ideal of surgery. With present-day limitations it is not always possible for one to satisfy this ideal. When one is confronted with a lesion of a nonsacrificiable vessel it is often necessary to approach the problem by "second-best" methods.

In summary, then, the modes of attack upon aneurysmal disease of a thoracic structure consist, per primam, of a reconstitution of the normal tube for the passage of blood. The "second-best" type of methods have had to be applied to the thoracic aorta during recent years and consist, essentially, of four modes of attack: (1) the repair of the wall of the aneurysm by internal plication, reconstituting a tube of normal caliber but allowing diseased walls to remain; (2) the promotion of a thick layer of blood clot within the aneurysm, in order to increase the protective character of the wall and thus reinforce the weakened area; (3) progressive obliteration of the aneurysmal sac by means of the promotion of periarterial fibroblastic reaction; (4) any combination of the preceding three types of procedure. It would seem reasonable to assume that a combination of any, or all, of the three indirect methods of approach would constitute the best method to substitute for direct and satisfactory reconstruction.

The method utilized in this study has relied upon the formation of a chronic, progressive, constrictive, periarterial, fibroblastic reaction in the hope of ultimate obliteration of the aneurysmal cavity, or at least sufficient strengthening of the wall to eliminate the threat of fatal rupture. In the latter period of the study we have added attempts to increase the thickening of the inner wall of the aneurysm along with the attack upon the outer wall. Polythene cellophane is undoubtedly only the forerunner of future preferable substances to produce periarterial fibroblastic reaction. Pearse,[1] in 1940, published studies upon the constrictive effect of the application of cellophane upon the aorta of dogs. His interest in cellophane arose, originally, with the work of Page,[2] in the application of this substance about the kidney in the promotion of experimental hypertension. This latter author noted "a marked tissue reaction within three to five days following the application of this substance. A constricting, dense, fibroblastic, collagenous formation about the surface of the kidney, varying from 3 to 5 mm. in thickness, was noted to be present within two weeks."

It was in 1941 that Harper and Robinson[3] reported a most interesting clinical application of this substance, namely, the use of cellophane about a ligated ductus arteriosus in which there was evidence of recanalization two weeks following the original operative procedure. At the original procedure, cellophane had been applied and the subsequent obliteration of the channel two months later was felt to be evidence that the reaction incited by the surrounding cellophane had contributed to the closure of this channel.

In 1943 two missionaries in Arabia, Harrison and Chandy,[4] utilized cellophane about aneurysms of the axillary artery in two patients. In the first patient there was evidence of obliteration of the lumen of this vessel in approximately nine months, while intervening secondary infection in the second patient necessitated secondary high ligation of the vessel and excluded the case from any satisfactory conclusions.

The irritating factors of cellophane have been the cause of considerable discussion among many workers. Some have used this material for the prevention of tissue reaction, while others have employed it with a diametrically opposed purpose. Thus, in contradistinction to the reports of Pearse, Page, Harper and Robertson, Harrison, and Chandy, there is the work of Donati[5] in 1937, and McKeever[6] in 1943, wherein the material was used in the treatment of arthritic lesions, with the hope of resurfacing mobile joints. This confusion led to the very valuable study carried out by Poppe and de Oliveira[7] in regard to the different physiologic properties of varying types of commercial cellophane. A series of animal experiments were conducted, utilizing five different basic types of this material. A very marked fibrous tissue reaction surrounding the section of the aorta in close proximity to Polythene variety of cellophane was constantly noted. Their studies promoted the following conclusions:

> (1) Moisture-resistant cellophane and types 300 P.U.T. 71, and 300 T.T. 62, cause minimal if any reaction. (2) Experimental studies have shown that in order to obtain the desired result it is necessary to use a particular type of cellophane, since some varieties produce no fibrosis. (3) Polythene cellophane has been found useful, not only in the treatment of aortic aneurysms, but also in the obliteration of a patent ductus arteriosus.

I derived my interest in this substance from ideas about the subject expressed by Dr. Evarts A. Graham in 1944. To my knowledge the first instance of the application of this substance to the human aorta was carried out by Graham in 1944.

It would seem well at this time to describe the technical considerations involved in the sterilization and application of this material. The technical name for the type of cellophane used is 1.5 Mil Polythene (NV-7-14).* This material has been sterilized by keeping it in 70 per cent alcohol for twenty-four to forty-eight hours prior to use. Following the exposure of the aneurysmal area of the vessel, plus at least two inches of the vessel above and below the site of disease; this material is applied in from two to four thicknesses so as to surround the diseased area and a one-to-two inch area of apparently normal vessel above and below the aneurysm. It is important to emphasize that the material is laid in contact with the aneurysm, and in no way constricts it. If a direct constricting action were used the danger of rupture of the vessel at the uppermost junction of the cellophane with the vessel would probably occur. The substance is used purely to stimulate a fibroblastic reaction about a diseased area.

Fluid is formed in contact with any foreign body. Therefore, this material may well float away unless definite methods are used to fix it in place. This fixation is carried out by suturing the material to near-by structures and wheresoever the wall appears sufficiently healthy. Fine arterial silk is used to sew the material directly to the vessel wall. Chemotherapeutic agents are utilized liberally, both before, during, and following the operation in order to prevent infection which is so likely to occur about a foreign body.

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*This material has been provided for experimental use by E. I. Du Pont de Nemours Company, Cellophane Division, Wilmington, Del.

To date, this material has been applied in thirty-two separate individuals, and in several of the patients more than one aneurysm has been treated. It has been felt that the application of this material is truly clinical experimentation, and therefore no patient has been subjected to the procedure unless the lesion appeared to be a definite threat to life should no treatment be instituted. This has constituted a very strict test of the material and therefore the final results would in no way be comparable to the application of this substance in considerably less-advanced lesions.

The predominant lesion treated has been aneurysmal disease secondary to syphilitic aortitis. The majority of such patients have been of relatively low economic and mental status, and it has been extremely difficult to maintain a satisfactory follow-up. Furthermore, in such patients wherein a fatal issue occurs, it has frequently been impossible to obtain permission for post-mortem examination. However, this study has not been confined to lesions of syphilitic etiology. Aneurysms of congenital origin, arteriosclerotic origin, and of dissecting type have been treated with cellophane application and their postoperative course observed. During the course of this study several of the individuals presented lesions in a sufficiently advanced state that extreme interference with respiratory function was already present. This allowed certain maneuvers of thoracic decompression to be carried out which were found to be necessary in order to prepare the patient for an open transthoracic procedure.

I have had opportunity to apply this substance to all areas of the thoracic aorta, both intra- and extrapericardial. The substance has also been applied to the innominate and left subclavian arteries and to the pulmonary arteries. Those of us concerned in this study have been impressed with the frequency with which areas of multiple aneurysmal disease are prone to occur in the patient with syphilitic aortitis. It has also been interesting to note the marked frequency with which aneurysmal disease may be present, and on fluoroscopy no pulsation of the presenting mass may be observed. The explanation for this phenomenon is really quite simple, in that on opening the thorax one frequently finds the overlying pleura markedly thickened, and only after the release of this overlying membrane does pulsation appear. In certain instances the lack of pulsation may be due to the degree of thrombosis within the aneurysmal sac. It has been our observation to note that only about 30 per cent of aortic aneurysms will be seen to pulsate in an unequivocal manner on fluoroscopic examination.

It does not seem necessary in a communication of this type to consider in any great detail the diagnostic measures involved in patients with aneurysmal disease. It is of utmost importance to realize that any mass, situated in the region of a vascular channel, has the potential of being aneurysmal in character. Again, it should be emphasized that the lack of pulsation does not in any way preclude the possibility of aneurysm. It has been our experience to note that mediastinal lesions which are associated with partial atelectasis, and especially if such atelectasis may be bilateral, should make one strongly suspicious of a vascular origin of the mass noted. It is, of course, obvious that there is a definite place for the application of angiocardiographic studies in patients of this type. However, in such patients in whom there is any major degree of bronchial compression, such that wheezes are noted on physical examination, it has been our policy not to carry out angiocardiographic investigation except in rare cases. This has been because of the associated bronchospasm which may occur witn angiocardiographic studies and such bronchospasm might constitute an unnecessary and hazardous risk.

No unusual types of visualization of the thoracic aorta have been carried out by means of Diodrast, but rather the study has been confined to injection into the basilic vein. I am cognizant of the studies carried out in which the material is introduced either directly into the aorta or into one of its major tributaries.

In view of the common knowledge of the diffuse character of syphilitic and arteriosclerotic disease of major blood vessels, it has not been felt advisable to instrument directly such an organ as the aorta. The roentgenkymogram has, of course, been of considerable disappointment in view of the fact that it only represents a permanent record of what may be seen with the fluoroscope, and the lack of pulsation under fluoroscopy would lead one to the conclusion which we have also achieved clinically, that the kymogram has been of no real value in the study of such diseases, unless definite pulsation is suspected on fluoroscopy.

It has been interesting to note, with Diodrast intravascular studies, the frequency of multiple aneurysmal disease in patients with syphilitic arteritis. One is, of course, concerned with the possibility of a Herxheimer reaction in association with the lesions of syphilitic etiology. To date, preoperative penicillin therapy has been instituted in such patients, and all have been carried to a minimum of 7 million units as a total including the pre- and postoperative course, in an attempt to treat the underlying etiologic agent. In the patients treated to date, no major serious complication of a Herxheimer type has been noted. The evaluation of the blood pressure in the right and left arm, and in both lower extremities, is a necessary investigative measure in all patients with central mediastinal mass and has been carried out in all patients with aneurysmal disease.

What may one expect to find in follow-up study of an aortic aneurysm which has been treated with cellophane application? It is reasonable to expect an initial enlargement of the shadow. This is, in part, due to a release of overlying constricting pleura and also due to formation of fluid about the foreign body which has been applied. There is no reason, from animal experimentation, to expect any dramatic changes. Actual constriction of the normal aorta of the dog may take three to six months to occur, and when one is dealing with a lesion of the massive size as is being described, one would hardly expect an obliteration of the channel, or even if the channel is constricted to a normal size the resulting wall should be so thickened as still to constitute a major x-ray shadow. An original enlargement of the shadow of the aneurysm has been noted, and then a return to the original dimension.

The next consideration to be dealt with is the matter of actual and potential complications of this surgical maneuver. In certain portions of this study one was treading upon previously unbroken ground. Therefore, it is natural to expect that certain errors, both in judgment and technique, were committed. It is felt in evaluating a new procedure that it is beneficial for us to publicize such errors, in the hope of forestalling its commission by others. In dealing with aneurysmal disease it is important to appreciate the limitations of x-ray investigation. It is common knowledge that an aneurysm pulsating constantly against a firm and rigid structure, such as bone, will undergo a weakening and thinning of this area of wall contact. Therefore, it is important not to unroof bone overlying an area of direct contact with the area of vascular disease. Great stress has been laid upon the lateral film in an attempt to evaluate the proximity of the aneurysm to bone, especially such structures as the sternum. In at least five patients what appears to be a good clear area has been seen between the aneurysm and the sternum (Fig. 1), and yet upon removing the sternum and leaving the posterior periosteum intact, it is obvious that an extremely thin-walled aneurysm is in direct contact with this periosteum. It is reasonable to feel that an aneurysm of thin wall containing blood would not be expected to present a dense or discrete shadow, especially in such a projection as the lateral film.

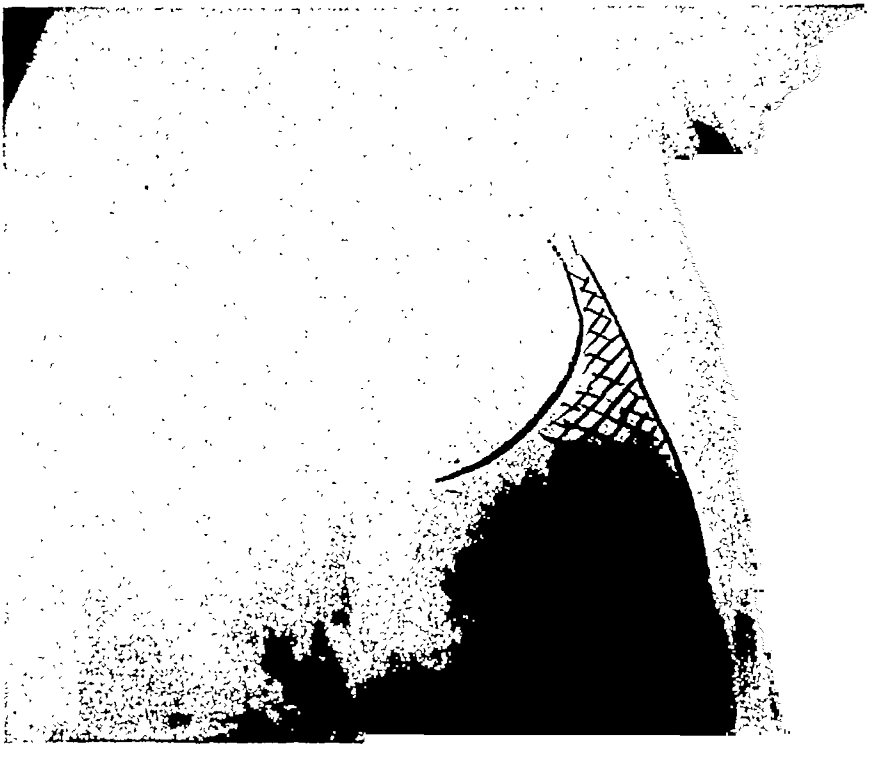


Fig. 1.—Patient, Mr. E. H. Lateral x-ray view to demonstrate lack of opacification when looking tangentially at an aortic aneurysm. Shaded area noted by cross-hatching appears clear, but actually aneurysm was in contact with the sternum throughout this area.

In the first two patients (Figs. 2 and 3) presenting massive aneurysm, pressing against the posterior surface of the sternum, there was major com-

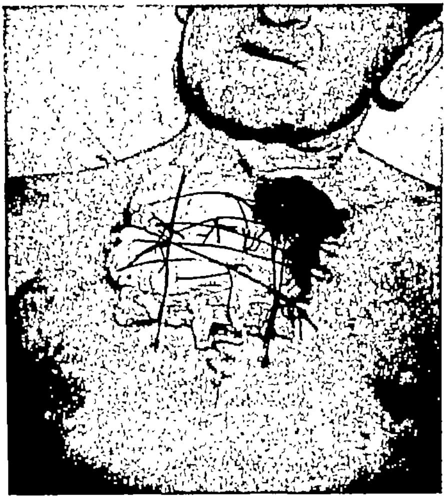


Fig. 2.—Patient, Mr. E. H. Photograph illustrating the inclusion of the dressing within stay sutures after the aneurysm illustrated in Fig. 1 ruptured during decompression maneuvers.

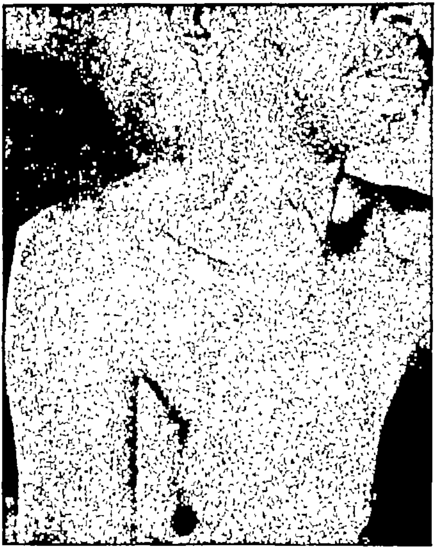


Fig. 3.—Patient, G. B. Photograph illustrating a large aneurysm arising from innominate artery and presenting in the clavicular and right cervical region. Aneurysm ruptured spontaneously during decompression through a thinned-out area of its wall pressing against the second rib.

pression of the lower trachea and both main stem bronchi. In attempting to decompress these two lesions, spontaneous rupture of the anterior surface of the aneurysmal wall occurred at the operating table. This catastrophe was dealt with by keeping pressure with the hands over the area of leakage, and sewing a large wide strip of thrombin-soaked Gel-foam to a strip of cellophane, and then placing sutures to near-by structures, so that this lay above the operator's hand; sutures for closure of the wound were placed, following which the hand was removed, the Gel-foam plaque applied immediately to the leaking surface, and the wound closed rapidly. This proved to be a temporizing method in both cases, inasmuch as one patient subsequently ruptured fatally on the sixteenth day, and the other on the nineteenth. At autopsy in the first patient it was found that rupture had occurred at a new site and there was apparent closure of the accidental rupture occurring on the operating table. In the second patient the fatal episode consisted of leakage through the original site of rupture. In both these patients, at the time the accident occurred, the ascending aorta was explored inasmuch as both were lesions of the innominate artery, in the hope that one might be able to ligate the base of the artery. However, in both cases the aneurysmal and syphilitic disease was involved down onto the wall of the ascending aorta in such a manner that no such measure could be undertaken.

The main lesson to be learned from this experience is not to remove bone directly in contact with aneurysmal wall. The second consideration is to appreciate that the lateral projection x-ray may not tell the exact proximity of the aneurysmal wall to such an overlying structure as the sternum.

A second, most interesting, complication of aneurysmal disease was also discovered by the process of trial and error. Many of the colored patients with aneurysmal disease originally enter the hospital due to the pulmonary complications of the aneurysm. Thus, they are admitted to the Medical Service because of pneumonia and atelectasis. In one such patient delayed resolution of the pneumonic process led to further detailed x-ray studies and a proper diagnosis of the underlying obstructive agent. There was a total atelectasis of the left lung, and a major aneurysm of the descending arch of the aorta. The patient had achieved maximum benefit from chemotherapeutic agents and medical therapy, and no major complaints relative to the respiratory function were present. The atelectasis persisted.

The patient was taken to the operating room, anesthesia induced, and endotracheal tube introduced. At the time of induction of the endotracheal tube apnea appeared, which was thought by the anesthetist to be due to depth of anesthesia. The patient was then placed in position for a left posterolateral approach. Despite release from anesthetic agents the patient's apnea persisted, so that he was returned to the supine position and the endotracheal tube removed. It was obvious that the patient was breathing with marked difficulty, as from obstruction. Bronchoscope was introduced and it was very alarming to visualize the severe degree of edema and constriction of the lower end of the trachea, as well as the entire left main stem bronchus, secondary to aneurysmal compression. Despite all attempts at resuscitative measures the patient died about four hours later.

Therefore, it was concluded that any patient having major tracheal or bronchial obstruction, secondary to an aneurysm, has not only compression but severe associated edema due to obstruction of venous flow, and that this obstruction must be corrected prior to any open intrathoracic operative procedures (Fig. 4). Again, by a process of trial and error and referral to previous works on decompression of the thoracic inlet, three major methods for decompression were evolved. This procedure is always carried out under Novocain infiltration and may be assisted by a very slow dilute intravenous drip of sodium pentothal. True general anesthesia is diligently avoided. It seems that with general anesthesia there is some relaxation of the support of the tracheal and bronchial wall which may convert a partial into a total obstruction.

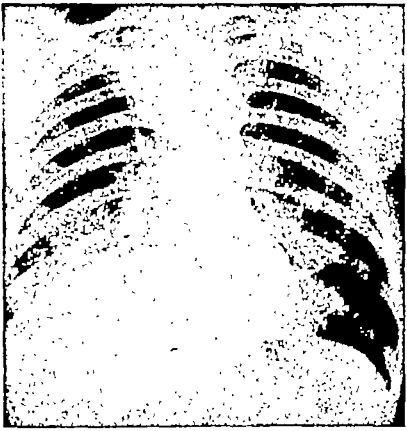


Fig. 4.—Patient, Mr. W. B. This x-ray illustrates the tracheobronchial compression produced by a syphilitic aneurysm of the innominate artery. Note the atelectasis of the right middle and lower lobes and obstructive emphysema of the right upper lobe. This patient withstood intrathoracic surgery well after a preliminary decompression operation on the right side

The measures which we have utilized for decompression are outlined in Figs. 5, 6, and 7 and consist, essentially, of enlarging the thoracic inlet by resection of a portion of the clavicle and upper two ribs over a lesion which is obstructing one bronchus. In some cases it is necessary to do this bilaterally, if both bronchi are involved and the lesion lies against the sternum. In lesions which are well separated from the sternum, such as an aneurysm of the descending portion of the arch or descending thoracic aorta, a sternal split with implantation of supporting wedge material, either of bone or metal, has been utilized. Following this operative procedure the patient frequently notes an almost immediate improvement in respiration. However, a change in x-ray and clinical findings is seldom noted prior to two weeks following operation, and it is often necessary to wait from three to four weeks to obtain maximum clinical benefit. This is

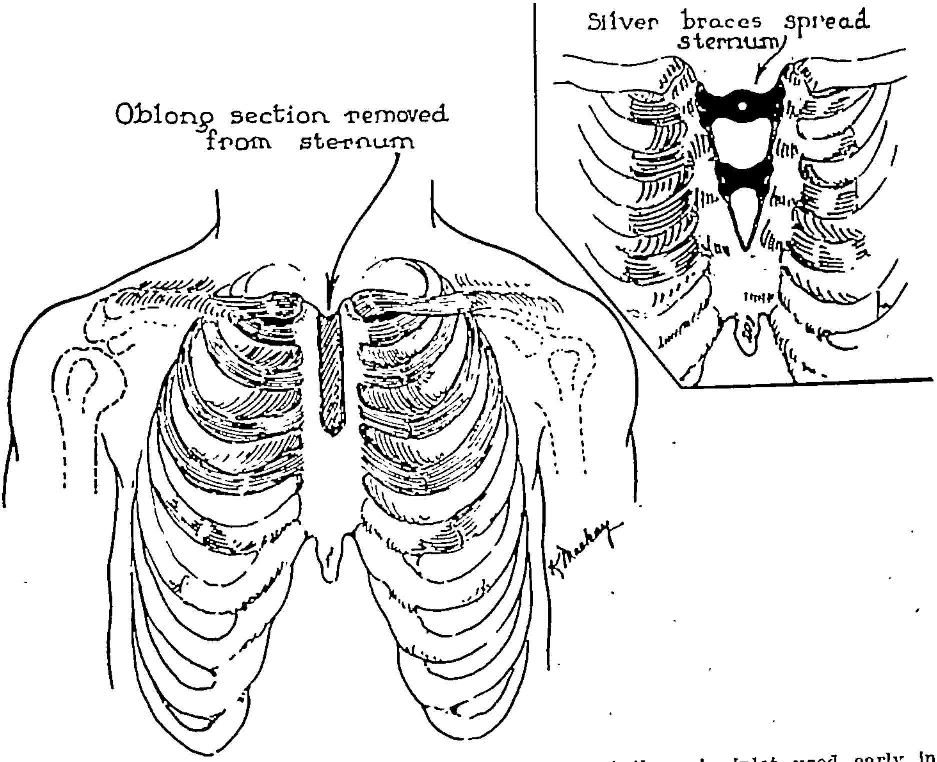

Oblong section removed from sternum
Silver braces spread sternum

Fig. 5.—Illustration showing method for decompression of thoracic inlet used early in this study. This method was found to be the least effective, as well as the most hazardous.

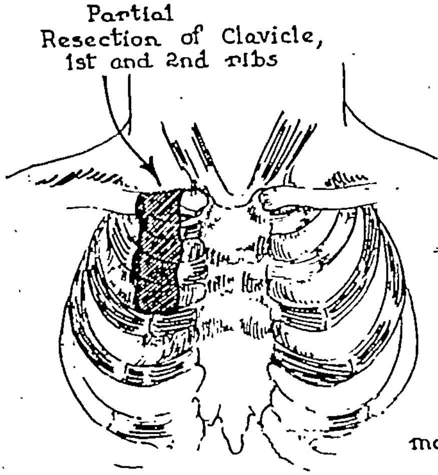


Fig. 6.

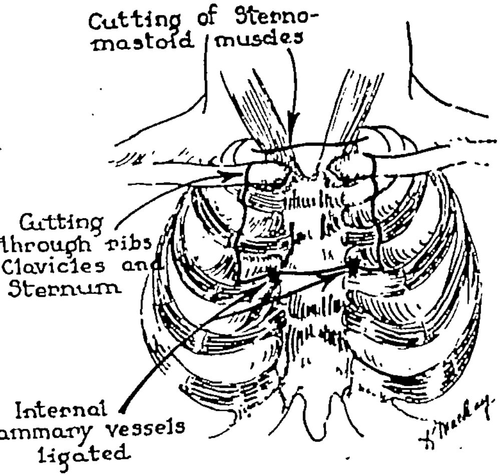

Cutting of Sterno-mastoid muscles
Cutting through ribs Clavicles and Sternum
Internal mammary vessels ligated

Fig. 7.

Figs. 6 and 7.—These illustrations demonstrate the most satisfactory method for decompression of the thoracic inlet. Fig. 6 demonstrates the amount of bone and periosteum resected at the first stage. Transection of the ligamentous structures behind the clavicle is not illustrated but the desired anterior displacement of the area outlined in Fig. 7 will not occur until these ligaments have been cut. Transection of the sternum is rarely needed and may be dangerous.

due to the time necessary for the resolution of the severe edema present secondary to the aneurysm.

A third complication which was noted to arise in the carrying out of this clinical experimentation has been the effect of irritating cellophane when brought into contact with the auricles. On three occasions the material has been applied within the pericardial sac. Two patients having a primary aneurysm of the ascending aorta were treated by the application of cellophane. The first operation (Fig. 8) was done early in the study, and irritative type cellophane placed about the area of aneurysmal disease. The postoperative course was uneventful, there being no arrhythmias or serious cardiac dysfunction noted. This patient was followed for a period of ten weeks following surgery and had resumed gainful occupation by that time. Unfortunately it has not been possible to obtain any follow-up data in regard to this patient since that time.

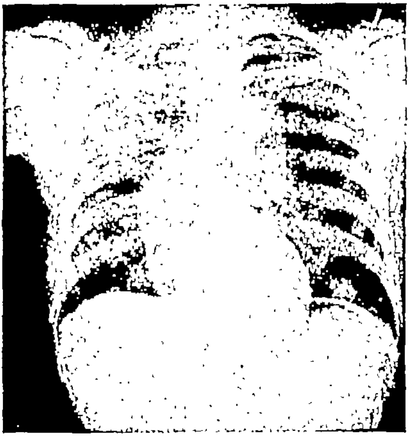


Fig. 8.—X-ray view demonstrating a large aneurysmal dilatation of the lateral wall of the ascending aorta. Note the secondary atelectasis of the right upper lobe as well as the obstructive emphysema of the right middle and lower lobes. Intrapericardial cellophane was applied in this instance.

A second colored patient with aneurysmal disease of the ascending aorta was treated by application of irritative cellophane ten months before this communication. In this patient a second outer layer of nonirritative type of cellophane was applied over the lower third of the ascending aorta in order not to bring irritative cellophane in contact with the auricular appendage. This patient's postoperative course was not complicated by any unusual cardiac arrhythmia. The outer layer of nonirritative type of cellophane was applied in this patient, due to an unfortunate experience gained on the second patient in whom intrapericardial cellophane was applied.

This patient (Figs. 9 and 10) was a 31-year-old white woman, in whom there had been a very rapid and progressive enlargement of a primary aneurysm of the main pulmonary artery. This lesion was treated by the primary application of Polythene cellophane, with no method of protection utilized to prevent contact of the cellophane with the auricles. The patient's postoperative course was uneventful until the eighth day,

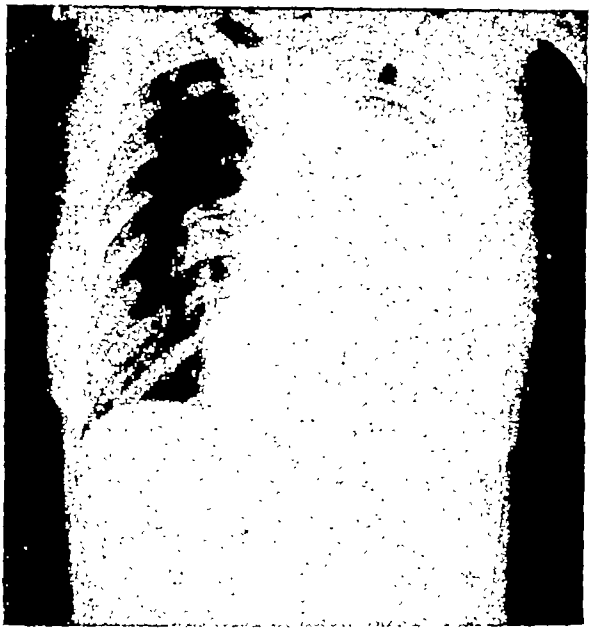


Fig. 9.—Patient, Mrs. R. W. X-ray film demonstrating a massive solitary aneurysm of the main pulmonary artery.

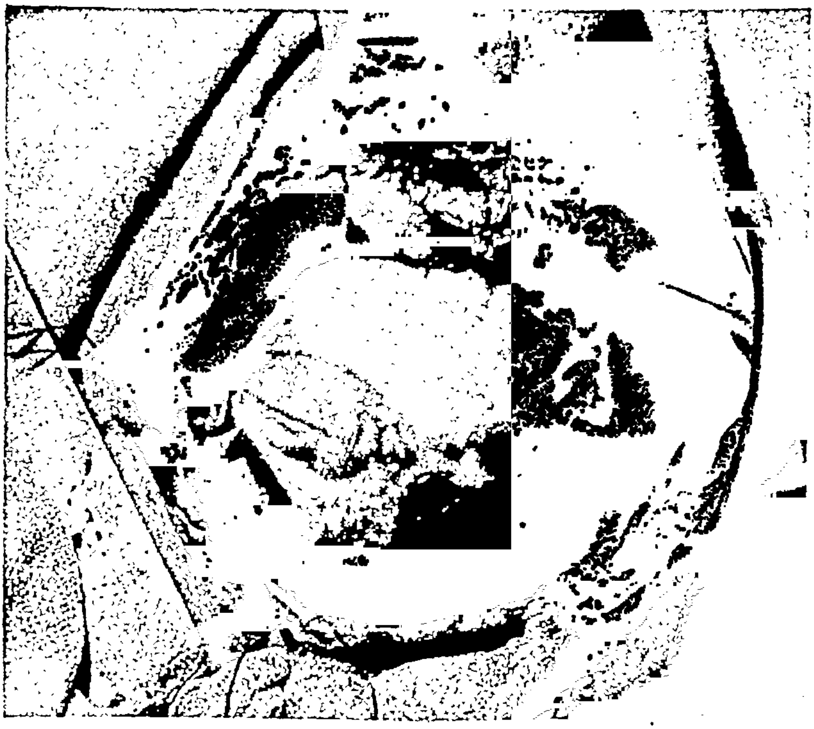


Fig. 10.—Patient, Mrs. R. W. Photograph illustrates the appearance of the lesion at the time of operation. Cellophane was applied within the pericardial sac in this instance without the use of a protective layer of nonreactive cellophane.

postoperatively, when she suddenly developed dyspnea and precordial distress apparently in association with ventricular fibrillation. The patient died very soon after the onset of this episode, so that exact details of the type of arrhythmia which might have been obtained from electrocardiographic studies were not available.

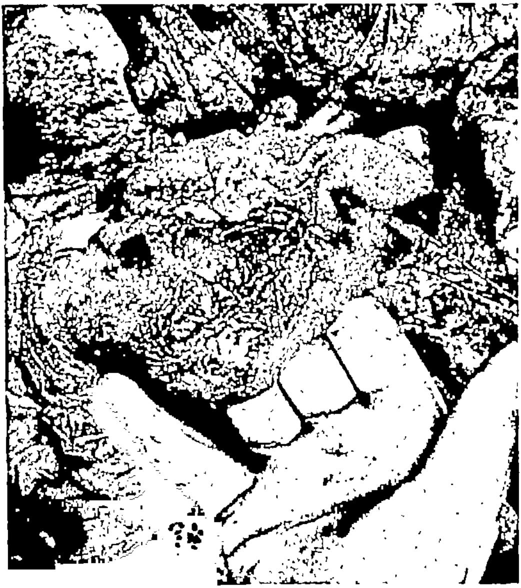


Fig. 11.—Patient, Mrs. R. W. Photograph taken of the postmortem specimen. Note nodular reaction over outer wall of the primary aneurysm of the pulmonary artery. Cellophane had been in place for eight days.

Post-mortem examination showed considerable fibroblastic reaction (Fig. 11) and response about the area whereupon cellophane had been placed. This was not confined entirely to the area of aneurysmal disease, but also involved the overlying pericardium and the portion of the left auricle which was in contact. An extremely small area of myocardial infarction in the terminal portion of the area of distribution of the anterior descending coronary artery was also present but was not felt to be of sufficient size to explain the acute fatal episode. Therefore, the presumptive opinion was that there are certain dangers inherent upon allowing irritative cellophane to come in contact with the auricular wall. The supposition is made that hyperirritability may be produced with consequent disturbance of both the pacemaker and conduction mechanisms. Certainly a solitary clinical experience of this type does not justify the formation of any permanent conclusions, but does indicate the need for further animal experimentation in this regard. Also, it is felt that until further data are obtainable, should one place cellophane within the pericardium, the addition of an external, nonirritative layer would appear to be indicated.

Our most dramatic clinical application of this procedure occurred early in the investigative period. A white man of 52 years (Fig. 12), with known positive serology, was admitted to the Grady Memorial Hospital in critical condition secondary to massive hemoptysis. Studies revealed the presence of a large aneurysm, occupying the mid-portion of the aortic arch and a second, even larger, aneurysm was present in the descending thoracic aorta just above the left diaphragm. The patient described very definite localizing symptoms as to the origin of the pulmonary bleeding, namely, at the base of the left lung. This patient continued to bleed very actively and it appeared that a fatal issue would ensue unless heroic measures were attempted.

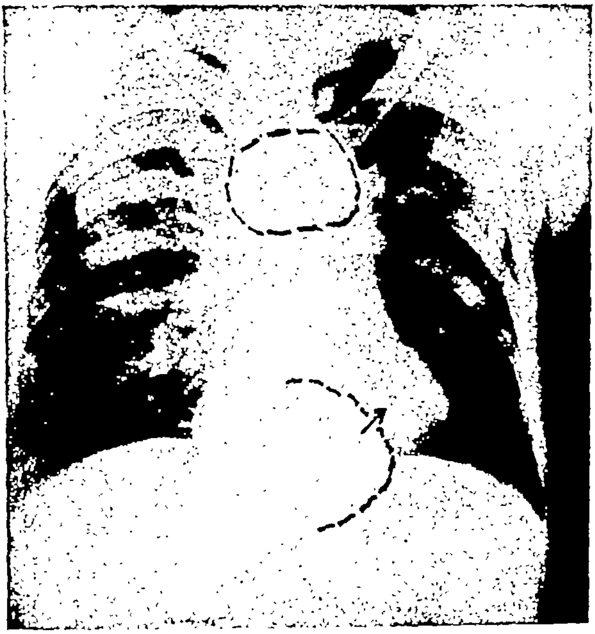
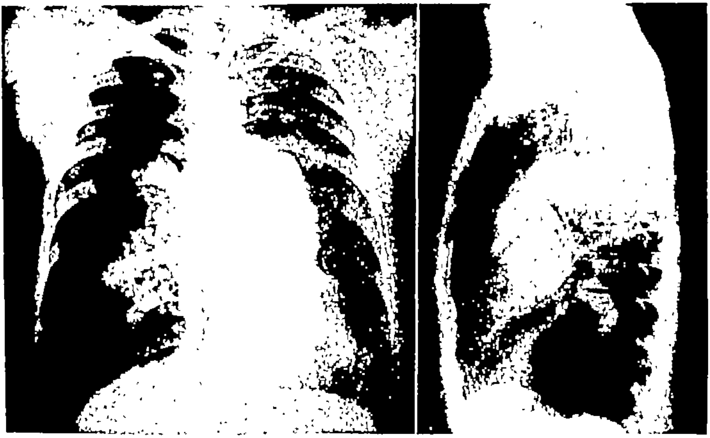


Fig. 12.—Patient, Mr. S. N. Posteroanterior x-ray view of the chest, showing the presence of multiple aortic aneurysms due to syphilis. Superimposed on this area are drawn the outlines of the large aneurysm of the mid-portion of the aortic arch as well as the supradiaphragmatic aneurysm with its point of communication with the right lower lobe of the lung.

Therefore, the patient was taken to the operating room, and through a left transpleural approach the aneurysm of the descending thoracic aorta was visualized, and a definite aortopulmonary fistula was found to be present. The adherent overlying lung was freed up and the fistulous communication clamped off at a 1 cm. distance from the aneurysm and transected. Therefore, a small portion of the lung was left adherent to the aneurysm and utilized in the closure of this area of defect in the aneurysmal wall. A free pleural graft was then placed over this area of repair in the aneurysmal wall and this aneurysm was surrounded with four thicknesses of Polythene cellophane. The defect in the left lower lobe was closed with interrupted silk sutures.

In view of the patient's general condition the second aneurysm which occupied the mid-portion of the aortic arch was not treated at this time. The patient's recovery was uneventful and he returned to a gainful occupation for a period of five and one-half months. He refused further surgery in relation to the aneurysm of the aortic arch. The patient died suddenly five and one-half months following surgery, but post-mortem examination was not permitted. For three weeks prior to death the patient had shown signs of increasing obstruction to the trachea and there was considerable hemoptysis at the time of his sudden death. It is suspected that the upper aneurysm may have eroded the trachea but exact knowledge in this regard is not available. It is felt, however, that this patient demonstrates a definite application for this method of procedure in the presence of fistulous communication between an aortic aneurysm and the pulmonary tree.

In only one other instance in our study group has this procedure been applied as an aid in the control of massive pulmonary hemorrhage. This patient is a 34-year-old white man (Figs. 13, 14, 15) who has been known to have some cardiac anomaly throughout his life. A cardiac murmur is stated to have been noted at the age of 6 years, with no antecedent history to suggest rheumatic fever. No cyanosis had been noted prior to the age



A. B.

Fig. 13. *A* and *B*.—Patient, Mr. T. F. L. Posteroanterior and left lateral roentgenograms showing massive aneurysmal dilatation of the pulmonary arteries, more marked on the left. Note particularly the "pseudo-embryo" shadow in the lateral projection. This type of shadow was seen in both patients having congenital aneurysms described in this communication.

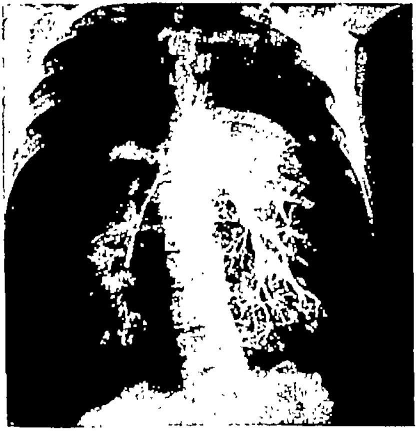


Fig. 14.—Patient, Mr. T. F. L. Lipiodol bronchogram demonstrating massive enlargement of the left pulmonary artery producing compression of bronchi most marked upon posterior segment of the left upper lobe.

of 29 years. At that age the patient began to note frequent recurring episodes of pneumonitis occurring with essentially equal frequency on the two sides of the chest. Increasing wheezing, cough, and occasional hemoptysis had been noted since the age of 31 years. Two years prior to seeing this patient, x-ray studies were carried out and a tentative diagnosis of mediastinal lymphoma made. He received two courses of deep x-ray therapy without change either in symptoms or x-ray findings.

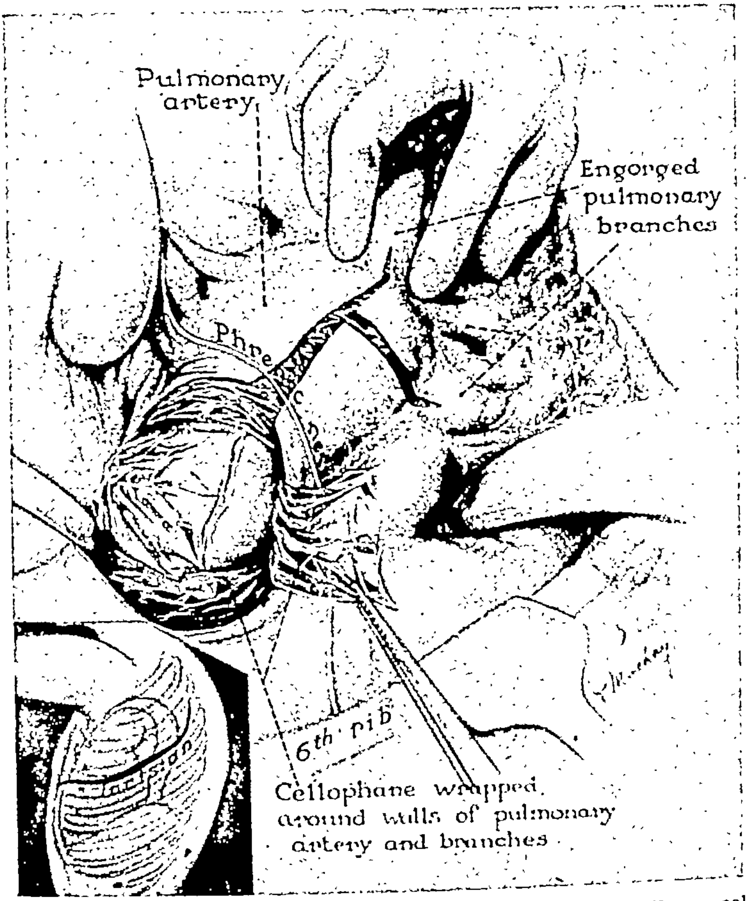

Pulmonary artery
Engorged pulmonary branches
Phrenic
Incision
6th rib
Cellophane wrapped around walls of pulmonary artery and branches

Fig. 15.—Patient, Mr. T. F. L. Artist's drawing showing Polythene cellophane being applied to massive aneurysm of left pulmonary artery. This substance was also placed about the segmental branches going to the left upper lobe. Insert at left shows the high lateral approach used.

This patient was first brought to my attention October, 1945, and was noted to have marked clubbing of the fingers, definite cyanosis, and a loud systolic murmur present in the second and third interspaces to the left of the sternum. Lipiodol studies presented evidence of massive enlargement of the pulmonary arteries, particularly the left pulmonary artery, and considerable secondary obstruction to the bronchial tree was noted. Cardiac catheter investigation revealed an extremely high pressure in the right ventricle, namely, 125 mm. of mercury, compared with a systolic blood pressure of 109 in both arms. The marked elevation of the pressure within the right ventricle was corroborated on two subsequent cardiac catheter studies, but these three studies showed some variance in the relative oxygenation of the blood obtained from the superior vena cava, right auricle, and right ventricle. On one of these examinations the examiner felt quite certain that he was able to pass the catheter into the left auricle through a large interatrial septal defect. During the subsequent two cardiac catheter studies this finding could not be corroborated.

The patient underwent angiocardiography on two occasions, but the findings were inconclusive relative to the presence of an atrial septal defect. He was kept under observation, and on Jan. 12, 1946, was admitted to the hospital apparently in extremis and suffering from extremely copious hemoptysis. The patient localized the site of bleeding in the region of the left upper lobe. The pulmonary bleeding persisted in such an active form that operative intervention was felt indicated. A left transpleural approach was used, revealing an extreme massive dilatation of the left pulmonary artery, such that at the point of emergence of this vessel from the pericardium its transverse diameter was found to be 12 cm. This dilatation appeared uniform throughout the course of the vessel and its primary branches, particularly to the left upper lobe. The vessel was therefore surrounded with two layers of Polythene cellophane and the branches to the apical and anterior segments of the left upper lobe were similarly surrounded, inasmuch as there was objective evidence of considerable saturation of these two segments with extravasated blood. In view of the extremely high pressure known to exist in the right ventricle and pulmonary artery it was felt unsafe to transect these two branches and it was also feared that suture lines might not hold in such a diffusely diseased vessel.

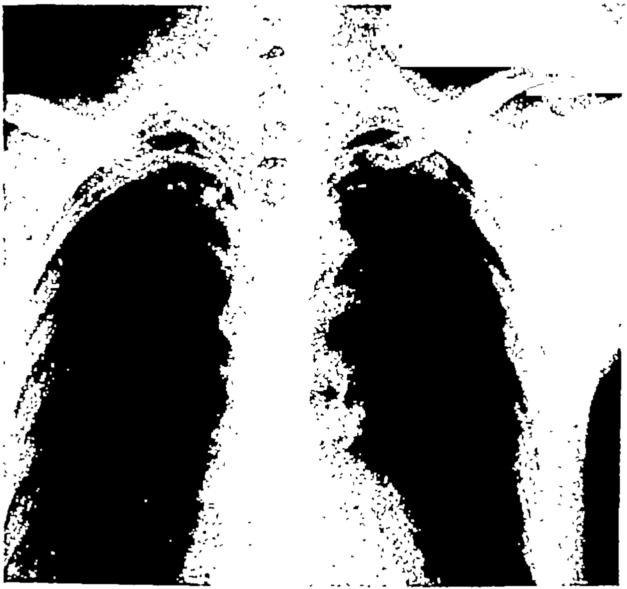
The postoperative course was essentially uneventful and two months following surgery the patient was able to return to gainful occupation. He has been kept under observation since that time and subsequent cardiac catheterization studies have shown an actual increase in the pressure present within the right ventricle. There has been a very definite improvement in the aeration of the left lung, but no dramatic evidence of decrease in size of the aneurysmal dilatation of the left pulmonary artery has been noted upon x-ray studies. It does appear to have considerably less pulsation visible on fluoroscopy than that noted on the right, and the right pulmonary artery appears to have increased somewhat. The patient has progressed sufficiently well clinically that we have not felt justified to carry out what is still an experimental procedure in regard to the right pulmonary artery. There has been no recurrence of hemoptysis, and although the patient shows some evidence of persistent decreased pulmonary and cardiac reserve, as well as an increase in pressure in the right ventricle, it is felt that operative interference has proved of clinical benefit to him.

A second patient (Figs. 16 and 17) with an unusual type of congenital vascular anomaly and associated aneurysm came under observation in March, 1947. This patient was a 27-year-old white man, a veteran, who had been complaining of some discomfort in the upper substernal area and left side of the chest for five months. X-ray examinations elsewhere had been interpreted as showing evidence of mediastinal lymphoma and the patient had been given a course of deep x-ray therapy. On examination at this hospital a very marked discrepancy between the systolic blood pressure in the right and left arms were noted, namely, a pressure of 130 in the right arm and 96 in the left. A machinery type of systolic and diastolic murmur was found to be present in the second left interspace, which could also be well heard in the left interscapular space. Fluoroscopic studies indicated a pulsatile character to the mass, and angiocardiogram was carried out. A diagnosis of unusual multilocular type of aneurysm of the descending portion of the thoracic aorta was made, and the patient was therefore subjected to exploratory left thoracotomy.

A most unusual condition was presented. There was no evidence of persistence of the ductus arteriosus. The descending portion of the aortic arch appeared to be made up of two parallel vascular tubes, with a communication between these two arteries, similar to that which might be formed by a side-to-side type of anastomosis. Thus, as one followed the aortic arch the left carotid artery appeared to arise in a normal position, as also did the left subclavian artery, except for the presence of definite aneurysmal disease involving its base and proximal 3 cm. The aortic arch then continued downward for approximately 2 inches and stopped as a blind end. This structure lay medial to another vascular tube which arose as a blind end 2 cm. distal to the base of the left subclavian artery, continued down lateral to the original tube forming the blind end of the descending arch, and then continued on downward as an apparently normal descending aorta. A very strong to-and-fro thrill was present over the point of side-to-side communication of these vessels, and a cluster of extremely thin-walled, cherry-sized aneurysmal structures presented about the entire area in which these two arteries were in apposition. The most advanced area of aneurysmal disease was noted at the blind end of the proximal limb and on the upper lateral wall of the distal limb, and these are the areas where it would appear there would be the greatest degree of intra-arterial pressure. In many areas these points of aneurysmal disease were so thin-walled as to be almost transparent, and it was not felt safe to remove the overlying pleura in all areas. There was also considerable disease on the posterior aspect of the anomaly eroding into the dorsal vertebrae.

Partial application of cellophane was therefore carried out, as it was felt impossible to free the area from its points of contact with vertebral erosion. The patient's postoperative course was uneventful and he was discharged from the hospital six weeks following surgery. However, one month thereafter the patient experienced severe lancinating pain in the upper left posterior part of the chest in conjunction with rather boisterous

Fig. 16.



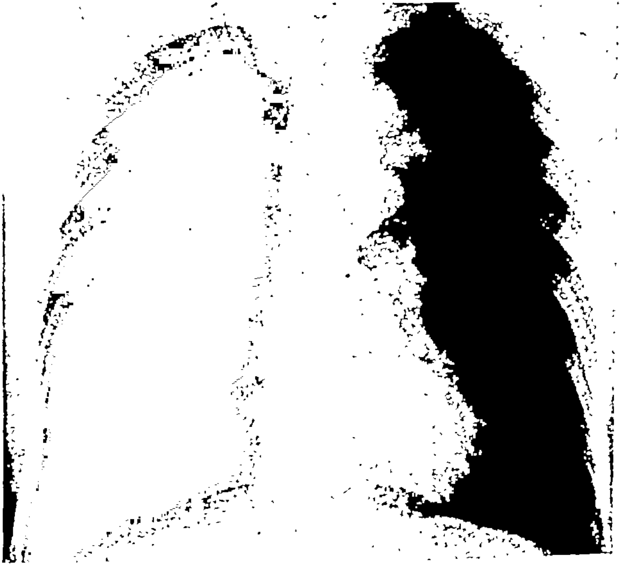


Fig. 17.

Figs. 16 and 17.—Patient, Mr. K. L. Fig. 16 shows the posteroanterior x-ray view of the chest. Note the rather vague nodular shadow in the region of the poorly outlined aortic knob. Fig. 17 demonstrates the filling of this shadow with 70 per cent Diodrast proving the presence of a congenital aneurysm of the aorta.

laughter. This pain persisted and the patient returned to the hospital, showing evidence of marked enlargement of the aneurysmal shadow. There was rather rapid onset of atelectasis in the left upper lobe thereafter, associated with an acute inflammatory reaction. The response to chemotherapy was slow and incomplete and the upper lobe showed evidence of multiple areas of abscess formation.

Cautious bronchoscopic therapy was then instituted with gradual but definite benefit to patient. Two weeks later the patient began to present increasingly severe hemoptysis which subjectively was arising from the left upper lobe area. He showed increasing blood pressure in the right upper extremity, and decreasing systolic blood pressure readings in the left upper extremity and in the legs. The patient finally died four and one-half months following cellophane application to the aneurysm with an episode of exsanguinating hemoptysis.

Autopsy was performed and it was found that the area of aneurysmal erosion, posteriorly, had probably leaked on several occasions and markedly displaced the cellophane from its original point of application. In fact, a considerable amount of hematoma fluid was present between the cellophane and the original aneurysmal wall, and the amount of reactive thickening of the wall was extremely disappointing. Fistulous communication between the areas of false aneurysmal sac at the left upper lobe bronchus was found, and no cellophane was found in this area. It was felt not to have played a role in the formation of this fistula. The lack of reaction about this aneurysm was felt to be due either to the early interposition of hematoma fluid between the aneurysmal wall and the overlying cellophane, or possibly due to the fact that the cellophane utilized had been kept in alcohol for several weeks prior to its application. There were not sufficient data available at this time, but it was believed that to prolong the soaking of Polythene cellophane in alcohol appears to diminish the degree of tissue reaction.

In general, this substance has been subject to rather severe clinical tests inasmuch as the procedure is still considered to be experimental, and therefore one is only justified in utilizing what appeared to be otherwise hopeless cases.

The first patient (Fig. 18) in whom this procedure was carried out at the Grady Memorial Hospital is a 48-year-old colored woman who first presented a baseball-sized aneurysm projecting through the right anterior chest wall and having partially destroyed areas of the first, second, and third ribs on the right, anteriorly. This lesion showed marked pulsation, and x-ray examination revealed the presence of a huge upper mediastinal mass. The patient was operated upon in October, 1945, through a right transpleural approach, revealing the presence of a massive aneurysm involving the ascending aorta and innominate artery, with a considerable area of overlying false aneurysmal sac. The superior vena cava was markedly flattened and widened. The aneurysm could not be totally surrounded but Polythene cellophane was applied to as much of the presenting surface as possible and about the base of the area of extension of the aneurysm through the anterior chest wall. The intrathoracic portion of the aneurysm having been treated, it was planned to carry out application of the irritative substance to the extrathoracic portion of the aneurysm at a subsequent stage. This aneurysm was syphilitic in origin. The second operative procedure was refused by the patient.

The immediate postoperative course was remarkably uneventful and during the ensuing months the area of visible and palpable extrathoracic aneurysm was seen to recede completely and lose its pulsatile quality. The patient did well for twenty-one months following surgery, at which time there began to be a gradual re-enlargement of the following antethoracic area of aneurysmal disease. The patient has continued to refuse further surgery, and this area has been noted to enlarge slowly and gradually up to the present time. It has now almost achieved its original size. The patient is now alive, thirty-one months following original application of cellophane.

The original intrathoracic shadow showed the typical initial period of primary enlargement, and has since returned to essentially its original size. At the time of cellophane application lipiodol was inected subpleurally over the lateral extension of the aneurysm, and this has been followed on subsequent x-ray studies and has been noted to move medially 1 cm. closer to the midline than it was at the time of immediate postoperative films.

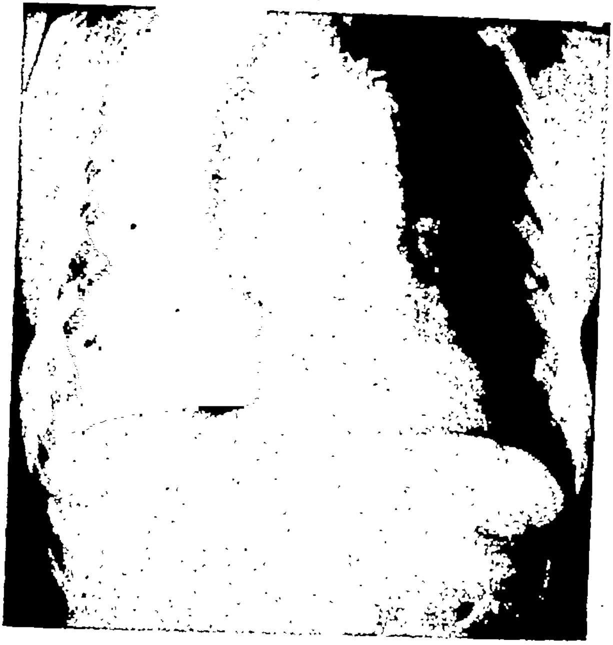


Fig. 18.—Patient, Mrs. M. J. This patient has a massive aneurysm of the innominate artery with a large false sac. The lesion had eroded through the anterior thoracic wall, presenting under the skin prior to cellophane application. Patient was still alive two years later.

One other type of aneurysm has been dealt with in this study, namely, dissecting aneurysm of the thoracic aorta. The application of this method of attack to this type of lesion appears very questionable on theoretical grounds. It has seemed justifiable to apply this method in rather desperate-appearing cases, especially with the plan in mind of application of the irritative substance to the aortic wall, proximal to the area of dissecting aneurysm. Particular attention has been paid to this factor because of the tendency for these lesions to dissect proximally and terminate with fatal rupture into the pericardial sac.

Two patients with dissecting aneurysm of the descending portion of the thoracic arch and the entire descending thoracic aorta have been operated upon. The first patient (Fig. 19) was operated upon in December, 1945, and a massive aneurysm found to be present. Cellophane was applied over the entire course of the aneurysm, with particular attention to surrounding the aorta with cellophane in the area of the transverse portion of the thoracic arch, extending two inches immediately above the apparent site of origin of dissection. This patient survived twenty-five months following the operative procedure. No dramatic change in the size of aneurysmal disease was noted. The patient was a narcotic addict prior to the time of cellophane application and continued to be, thereafter. He did not return to gainful employment. He did experience an episode of acute upper abdominal pain seventeen months following the original intrathoracic procedure, which was found to be due to a perforation of a peptic ulcer of the duodenum, which responded well to immediate surgery. The patient experienced considerable decreased respiratory reserve due to extrinsic compression by the aneurysmal mass upon the left lung. This phenomenon was present prior to operation and was not markedly benefited by the procedure. The patient died suddenly twenty-five months following the original operation and unfortunately post-mortem examination could not be obtained.

A second patient (Fig. 20) with a fairly similar, but less advanced, stage of disease of dissecting aneurysm was treated in April, 1047. This patient was seen two weeks following apparent original episode of dissection of the aortic wall and was treated by bed rest for six weeks. He experienced persistent pain and extremely rapid weight loss. The serology in both patients with dissecting aneurysm showed no evidence of syphilitic disease.

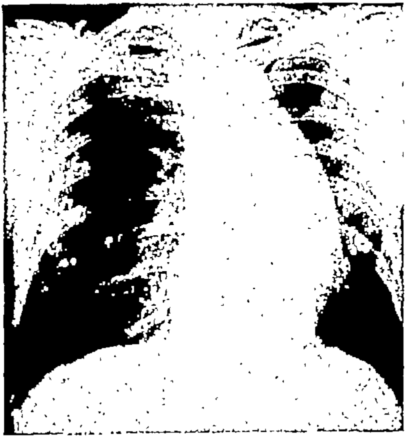


Fig. 19.—Patient, Mr. J. C. C. This x-ray film illustrates a massive dissecting aneurysm of the descending thoracic aorta. Note the associated emphysema and compression-type atelectasis of the left lung.

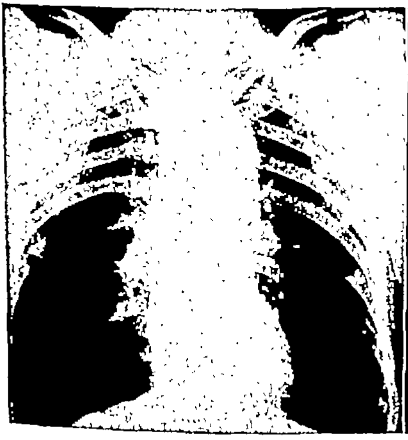


Fig. 20.

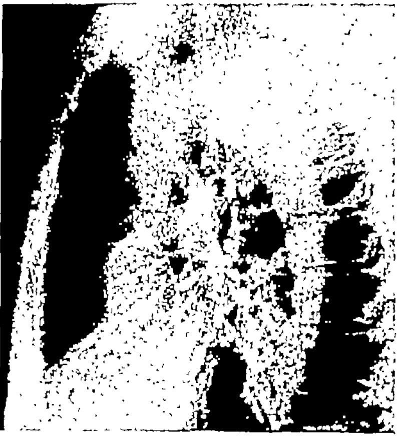


Fig. 21.

Fig. 20.—Patient, Mr. T. F. T. Posteroanterior x-ray view showing the shadow cast by a dissecting aneurysm of the aortic arch and upper portion descending thoracic aorta.

Fig. 21.—Patient, Mr. T. F. T. Angiocardiogram taken in the left lateral projection. Note the double shadow presented. The dense shadow is produced by Diodrast passing through the normal lumen; the lighter shadow represents the area of dissection.

Eight weeks following the original acute episode, the second patient was studied by angiocardiography and a very good demonstration of the lesion was obtained (Fig. 21). It was possible to carry out complete surrounding application of cellophane to this lesion, involving considerable area of the aorta above and below the points of dissection. The patient experienced no difficulty following surgery, and two months after operation had regained the thirty-five pounds which he had lost and returned to his previous gainful occupation. He has had no symptoms since that time and the x-ray studies show no visible change in the size of the original lesion. There has been no change in the blood pressures in the upper and lower extremities, postoperatively, in comparison to those obtained prior to surgical intervention. The progress of this second patient has been very gratifying to date, but it is felt that until further data become available that it is perfectly possible that a similar pleasing course might have occurred had no surgery been performed.

At the completion of the first year of this study, our data were reviewed and we were impressed by the fairly uniformly satisfactory results which had been obtained in patients in whom the entire area of aneurysmal disease could be surrounded by cellophane. However, the majority of patients presented lesions in which a large area of the aneurysm could not be surrounded, due to erosion into overlying or underlying bony structures. In 40 per cent of these patients we did apparently achieve a definite decrease in the amount of pain experienced by the patient by the application of this substance. In the other 60 per cent no apparent benefits were obtained. In the majority of these patients follow-up studies have demonstrated a progression of their disease and fatal issue has occurred in 65 per cent from two to fourteen months following surgery.

Realizing the variance in prognosis and duration of life with this type of aneurysm, it is not felt that life has been prolonged in any of these patients, and the only benefit noted in these advanced cases has been reduction of pain in 40 per cent. Furthermore, the majority of these patients have died within four months of institution of operative therapy and it has been felt that this type of lesion needs a combination of methods in the therapeutic approach. Therefore, in four instances during the past year patients with advanced aneurysmal disease have been treated by a combination of partial cellophane application, plus internal wiring. In one patient with a very massive aneurysm of the transverse and descending portions of the aortic arch, this procedure was carried out and the patient died suddenly ten days following surgery and was found, at autopsy examination, to have delivered a large embolus up through the left common carotid artery. A considerable amount of fresh clot was noted within the aneurysm, and there appeared to be adequate early, peri-arterial reaction.

Two other patients with lesions of the descending thoracic aorta have been similarly treated, and now at three and five months postoperatively they appear to be progressing satisfactorily. A fourth patient (Figs. 22, 23, 24, and 25) with similar disease was operated upon ten months before this communication, and his course has been sufficiently dramatic that it is felt worthy of specific note. This patient was a 48-year-old colored man, a veteran, who was sent to the Lawson Veterans Administration Hospital. The lesion had progressed to sufficient size that the overlying skin showed definite early ulceration. Immediate surgical intervention was felt indicated, so that a right anterior transpleural approach was utilized. It had been hoped that it might be possible to occlude the innominate at its base, but the area of aneurysmal disease was found to extend for a considerable distance down the ascending aorta so that cellophane was applied about the base of the innominate artery, as well as the area of disease of the ascending aorta. This substance was also applied, to as great an extent as possible, about the innominate artery.

Fig. 22.

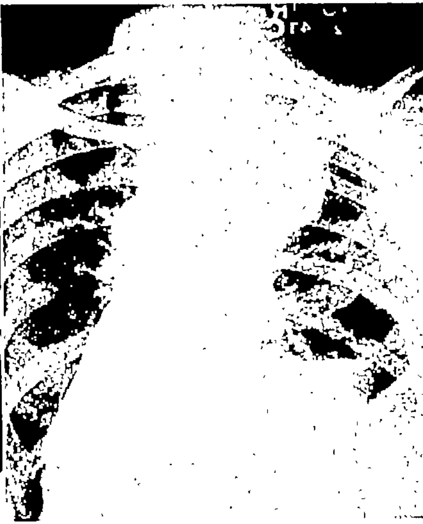


Fig. 23.

Figs. 22 and 23.—Patient, Mr. A. M. Fig. 22 illustrates the large aneurysm of the innominate artery plus the large false-sac in the suprasternal area. Fig. 23 represents an x-ray view taken six days following surgery. The false-sac has refilled following the original aspiration. Silver wire placed in this sac does not show up well on the film.

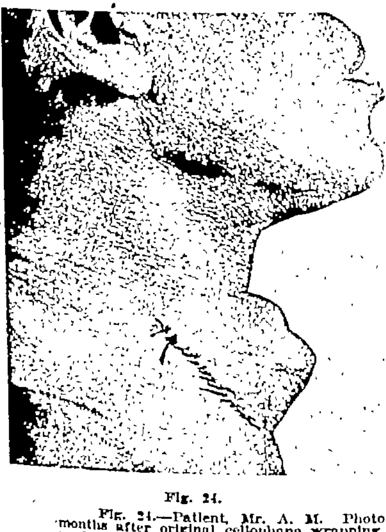


Fig. 24.

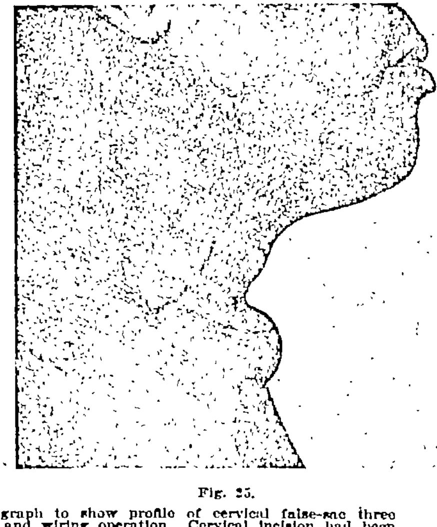


Fig. 25.

Fig. 24.—Patient, Mr. A. M. Photograph to show profile of cervical false-sac three months after original cellophane wrapping and wiring operation. Cervical incision had been made for proposed purpose of inserting additional wire but aspiration revealed original communication with parent aneurysm was now occluded. Irregular contour in this photograph is produced by the contained wire after contents were aspirated.

Fig. 25.—Patient, Mr. A. M. Profile photograph taken ten months after original operation. Lesion has since become progressively smaller and now measures 1 cm. in diameter. Patient is clinically well.

It was felt that we were able to apply the substance to approximately 80 per cent of the surface of the aneurysm.

Particular attempts were made to place the cellophane about the base of the projection of the aneurysm up into the false sac which presented in the neck. Following application of the substance, a large spinal needle was introduced through the wall of the aneurysm up into the sac presenting in the neck. There appeared to be evidence, upon insertion of the needle, that the inner wall of the innominate aneurysm contained a thick layer of blood clot. It was found that the projection of the aneurysm up in the neck could be aspirated of old hematoma fluid, and that the area of communication with the primary aneurysm was apparently small as evidenced by relatively slow refilling of the aneurysmal sac. A considerable amount of silver wire was then injected into this sac through the spinal needle before mentioned, and the chest wall closed after removal of the needle and application of fibrin-foam to the site of needle puncture.

The patient's postoperative course was complicated by a certain amount of atelectasis and episodes of paroxysmal auricular fibrillation. An outer protective layer of nonirritating cellophane was not utilized as much as it was felt that the area of ascending aortic aneurysmal disease did not necessitate the application of irritating cellophane in a region which might irritate either auricular or ventricular wall. The patient's progress was slow and the area of aneurysm presenting in the neck remained approximately 60 per cent of its preoperative size, became definitely less pulsatile, and allowed the overlying skin to resume the normal texture and appearance. Two months following the original operation it was considered that it might be advisable to implant a larger amount of silver wire into the false sac presenting in the neck. Therefore an incision was made in the neck, on its right lateral aspect, and the wall of the aneurysmal sac visualized. The needle was inserted into this wall. A surprisingly thin type of hematoma fluid was encountered which was aspirated. The original wire could be palpated at this time.

Surprisingly, there appeared to be no tendency for this sac to refill, so that the operative procedure was terminated and the patient returned to the ward. The false aneurysmal sac in the neck was noted to re-enlarge gradually over a period of eight days. A needle was again re-inserted into the sac through the tissues of the neck and the cavity evacuated. Further observation revealed that this procedure was necessary at about seven- to ten-day intervals and he was returned to another veterans' facility three months following the original operative procedure. Ten months after the original operation the patient presented a small firm nonpulsatile lesion in the supersternal notch measuring 2 cm. in diameter and he has not required aspiration for the past five weeks. No appreciable change in the size of the intrathoracic masses is noted on subsequent x-ray studies. It is now planned to study the lesion with angiocardiographic visualization and to follow the patient periodically. It is felt that this patient has demonstrated unequivocal evidence of the value of a combination of methods of approach to an advanced aneurysmal lesion.

SUMMARY AND CONCLUSIONS

I wish to re-emphasize that this report must be considered preliminary in type and that the findings to date are not conclusive. This study has involved the application of experimental methods to human aneurysmal disease in 23 patients. The experimental character of this approach has required the application of this substance to disease in an advanced and apparently hopeless stage. This has produced a rather severe clinical test of the method. Unfortunately this has required that a large percentage of the patients present lesions which cannot be totally surrounded by the irritative substance, Polythene cellophane. The results have been strikingly and uniformly more beneficial in those patients in whom total surrounding of the lesion has been achieved.

The majority of the lesions treated have been of syphilitic origin. Unfortunately, in the main, these patients have been members of the indigent, colored, and lower intelligence bracket. This factor has markedly hindered the adequacy of follow-up studies and, in particular, has permitted remarkably few postmortem examinations in patients wherein a fatal conclusion occurred. In certain instances, falsification of name and address have deprived us of any follow-up knowledge of patients following their discharge from the hospital. Adequate clinical follow-up studies and tissue examination, to demonstrate the effect of Polythene cellophane upon the human tissues, is not available. Certain errors in the management and technique of the treatment of these patients have occurred, especially in the early stages of this study, and we have felt that it is particularly important for this communication to draw special attention to these failures. Certain methods which we have instituted in order to eradicate the repetition of such disasters have been described.

We wish particularly to re-emphasize the danger of separating an area of aneurysmal disease from a point of bony contact. Furthermore, we have attempted to stress the frequency with which aneurysmal disease in proximity to the trachea or main stem bronchus may produce an extremely diminished vital capacity, pronounced endobronchial or endotracheal edema, and preclude the possibility of open thoracic procedures until certain corrective measures have been instituted. We have utilized two main methods of enlargement of the thoracic inlet. In patients in whom the primary disease is at a sufficient distance from the upper sternum, a one-stage split of the sternum with application of internal supportive splints to maintain the spreading of the sternum is recommended.

In the majority of the patients we have found it necessary to utilize a second type of decompression, namely, removal of a portion of the clavicle and first two ribs with particular attention to transection of the ligaments behind the clavicle to allow anterior elevation of the sternum. It has usually been found necessary to carry out this procedure bilaterally, and it should not be done under general anesthesia. The patient may note immediate clinical benefit relative to respiratory capacity following this decompression measure. but it is our experience to note that it usually requires from two to four weeks for adequate re-aeration of the lung to occur and edema of the airway to disappear.

One is impressed with the value of angiocardiographic visualization in patients having unexplained mediastinal masses or known aneurysmal disease when surgery is considered. It seems that approximately 70 per cent of aneurysms of the major thoracic vessels do not show evidence of pulsation on fluoroscopy, and this is felt to be due to either marked thickening of the perivascular structures, intra-aneurysmal formation of clot, or a combination of the two. It is felt important to stress the frequency with which aneurysmal disease may be multiple when one is confronted with a patient having aneurysms secondary to syphilis.

The technique of the sterilization and application of Polythene cellophane has been described. Particular stress has been placed upon the need of fixing this material to the aneurysm, or to surrounding structures, to prevent its displacement following operation. Further investigation is required relative to the optimum of time for soaking this material in alcohol, but the early impression is gathered that immersion in alcohol longer than forty-eight hours may decrease the efficiency of the irritative mechanisms.

The later stages of this study have shown it advisable to use a combination of therapeutic approaches to aneurysmal disease wherein complete surrounding of the lesion is not possible. We have utilized a combination of application of cellophane externally, and internal wiring. In three of four instances this has been felt to provide a definite improvement on the previous method of a solitary therapeutic approach to these advanced lesions.

To date I have applied cellophane to thoracic aneurysms in thirty-two instances, using the addition of internal wiring in four of these patients. The majority of the lesions have been syphilitic in origin. Two patients having aneurysmal disease presumed to be congenital in origin have been treated. In one of these the lesion was a diffuse aneurysmal dilatation of the pulmonary artery, probably secondary to a massive interatrial septal defect. In the second patient a most unusual congenital anomaly of the descending portion of the thoracic aorta was presented. This lesion could not be completely surrounded and definite benefits from this type of surgical intervention were not obtained. Should such a lesion be again encountered one would have to consider strongly the resection of this area of the aorta and some method of reconstitution of the vascular channel. One aneurysm of the main pulmonary artery was treated, which was found to be in association with diffuse sclerosis of the pulmonary and systemic arteries in a young female. It is doubtful whether this procedure would have benefited the patient had a successful postoperative course occurred. It is felt that this patient presents evidence that irritative cellophane should not be allowed to come in contact with irritable areas of the heart wall. It is felt that when the substance is placed within the pericardium an inner layer of nonirritative cellophane should be utilized.

This procedure has been applied on two occasions in our series in the presence of active, massive hemoptysis. In one of these instances it was used as an aid in the closure of a fistula between the aneurysm and the lung.

In conclusion, it is felt from these studies that a sufficient amount of benefit has been derived in these far-advanced patients to consider continued use of this method of therapeutic approach. The combination of the indirect methods of correction of aneurysmal disease probably presents certain advantages, not inherent in any one method of indirect approach alone.

ADDENDUM

Further experience has shown the Polythene cellophane should be prepared by steam sterilization for twenty minutes. Alcohol may discolor the initiating substance dicetyl phosphate.

REFERENCES

1. Pearse, H. E.: Ann. Surg. 112: 923, 1940.
2. Page, I. H.: J. A. M. A. 113: 2046, 1939.
   Idem: Am. J. Path. 16: 211, 1940.
3. Harper, F. R., and Robinson, M. E.: Am. J. Surg. 64: 294, 1944.
4. Harrison, P. W., and Chandy, J.: Ann. Surg. 118: 478, 1943.
5. Donati, D.: Bull. d. sc. med., Bologna 109: 425, 1937.
6. McKeever, D. C.: J. Bone & Joint Surg. 25: 576, 1943.
7. Poppe, J. K., and de Oliveira, H. R.: J. Thoracic Surg. 15: 186, 1946.

DISCUSSION

DR. J. KARL POPPE, Portland, Ore.—I want to congratulate Dr. Abbott on his relatively large series of cases for this early stage in the surgical control of intrathoracic aneurysms.

During the past two years I have run across approximately a dozen aneurysms, of which only six were actually operable. The majority of these inoperable cases were in cardiac decompensation as a result of dilatation of the aortic ring and aortic insufficiency. A certain number of the patients were too advanced in age to consider for any major surgery. I think that applied to all of the arteriosclerotic dissecting aneurysms I saw. The patients were all over 70 years of age, with an absence of pulsation in the lower extremities.

The procedure seems a little too early in its infancy to permit undue risks in accepting this type of patient. Other contraindications were complete compression and stenosis of the main bronchi, which seemed to contraindicate any major surgical procedure.

I am very happy to have been able to contact the first patient in whom we used Polythene cellophane. The social service here in St. Louis located this patient yesterday—twenty-three months postoperatively.

(Slide.) This type of fusiform aneurysm of the descending aorta still seems to be the most satisfactory one of the group for cellophane wrapping. This was the first patient whose aneurysm was wrapped with Polythene cellophane. He is now twenty-three months postoperative and working every day. He was on relief for at least two years, suffering very severe pain in the back and a throbbing pain in the anterior part of the chest, which I understand has been relieved.

(Slide.) There is another type of aneurysm which has proved very satisfactory—a fusiform aneurysm of the descending aorta, plus the distal part of the arch.

The picture on the right was taken two months postoperatively, and that seems fairly characteristic of these postoperative films in that there has been no apparent decrease in the size of the shadow, that the compression apparently occurs internally, and the shadow on x-ray examination may even increase in size.

(Slide.) This represents another fairly satisfactory aneurysm in which we have been unable to evaluate completely the results, due to the presence of generalized arthritis in this patient. Some days he feels he is cured and then again, on rainy days, he complains of generalized aches all over the body.

(Slide.) I am showing this slide partly for Dr. Renault de Oliveira who has returned to Brazil. This was one of the original dog aortas wrapped with Polythene cellophane. A normal section of the same dog aorta is on the right side.

(Slide.) Dr. de Oliveira carried out further experimental work in an attempt to cover the active polythene cellophane with a nonreactive type of material to slip underneath the superior vena cava, for instance, on aneurysms of the ascending aorta.

The picture on the left shows the Polythene cellophane which has been covered with 300 PUT nonreactive cellophane, which apparently reduces the reaction of the Polythene cellophane to such an extent that it seems undesirable to use, except over very limited areas around vital structures. It reduces the external compression so that it detracts from the original purpose of the Polythene.

DR. ABBOTT.—I have very little to add except for the fact that we have had patients in whom there was such a degree of bronchial compression that the physical findings appeared to be those of pulmonary edema and they had been diagnosed as "patients with cardiac failure." Following decompression, these changes were noted to disappear and the patient became eligible for intrathoracic surgery.

I believe that the observation justifies further stress relative to the early increase in the size of the x-ray shadow following operation. We feel that this is due to two factors, namely, (1) the release of the constricting overlying pleura, and, (2) the initial formation of fluid about the cellophane as the fibroblastic reaction is set up.

The observations in this work have lent emphasis to the original findings of Poppe, that considerable, and even dramatic, relief from pain may be obtained when an aneurysm is only partially wrapped. There is no question but that one must not dissect aneurysms away from points at which they press upon bone, for in such areas the wall may be so thin as to cause spontaneous rupture.

ADENOMA OF THE BRONCHUS: ENDOSCOPIC TREATMENT IN SELECTED CASES

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IN 1935 Rudolph Kramer and the author[1] reviewed a group of cases of adenoma of the bronchus and referred to the comprehensive publication on these tumors by Wessler and Rabin.[2] We stressed the criteria for the pathologic diagnosis of bronchial adenoma and its differentiation from carcinoma as demonstrated by Rabin and Moolten.[3] A distinction was drawn between the endobronchial, pedunculated, polypoid tumors and the intramural or extrabronchial type of growth. For the latter, lobectomy was recommended.

Twenty-three cases of adenoma of the bronchus were reported, including four instances that were discovered at autopsy. In nineteen cases the diagnosis had been made by examination of a bronchoscopic biopsy. Two of these patients died of hemorrhage and infection and three were not suitable for endoscopic therapy because of extrabronchial extension. The results of the remaining fourteen, adequately bronchoscopically treated patients were submitted. Nine were then considered either cured or symptom-free and five had persistent, minimal symptoms in spite of bronchoscopic therapy, including diathermy and radium.

Results of further observation of these endoscopically treated patients for the following thirteen years reveal the fact that seven remain cured or completely symptom-free. Of the remaining seven, two died of bronchial bleeding and five were advised to have lobectomy. Surgery was recommended in the latter because of exacerbation of lung suppuration with hemorrhage or the impossibility of eradication of the neoplasm by bronchoscopic means. Thus, seven of the original nineteen bronchoscopically treated cases remain cured or symptom-free (Table I).

In the recent literature there has been much critical discussion as to the ultimate value of endoscopic therapy and a definite trend toward surgical extirpation of these neoplasms has resulted. C. L. Jackson, F. W. Konzelman, and C. M. Norris[4] contend that if success is attained in accomplishing drainage and reaeration of the lung, distal to the obstruction, there is no urgent need for surgery. They report twenty cases of adenoma, in seventeen of which symptomatic improvement was obtained by bronchoscopic therapy, only three patients requiring lobectomy. They believe that bronchial adenomas do not metastasize and show no inherent tendency to become malignant. In their opinion, the incidence of extrabronchial growths is overemphasized. Of six cases of adenoma cited by R. Adams,[5] bronchoscopic removal sufficed in two patients and the other four required pneumonectomy.

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TABLE I

Analysis of Results in First Publication, 1935	
23	cases of adenoma originally reported
−4	post-mortem findings—never bronchoscope
19	diagnosed by bronchoscopy
−2	died of hemorrhage and infection
−3	not suitable or refused endobronchial therapy
14	adequately treated cases—by endoscopy
9	cured or symptom-free
5	persistent minimal symptoms
Results After 13 Years' Additional Observation, 1948, on the Above 14 Cases	
7	cured or symptom-free
2	died of bronchial bleeding
5	referred for surgery

John R. McDonald[6] reported thirty-eight cases of adenoma, twenty-three of which adenomas were diagnosed bronchoscopically. In the remaining fifteen, the microscopic diagnosis was established from surgically removed lungs and post-mortem material. In this group of fifteen gross specimens, they found tumor invasion of the bronchial wall in thirteen. Only two showed no infiltration of the neoplasm intramurally or peripheral to the bronchial cartilage. In the latter two specimens the main mass of tumor was within the lumen of the bronchus.

One must not be too impressed by the high incidences of bronchial wall infiltration in this group of fifteen patients because, ostensibly, they represent conditions not suitable for endoscopic therapy and hence treated surgically. McDonald[6] refers to an isolated endobronchial tumor which was 1.8 cm. in diameter, with a pedicle of but 3 mm. on cross section. In one case infiltration of the lymph node due to direct invasion was found.

W. S. Tinney[7] discussed the conservative and radical approach in the entire group of cases reported from the Mayo Clinic and recommended surgery if the growth is inaccessible or recurs after removal. Of seventeen cases reviewed by R. Adams[8] of Boston, five patients were treated endoscopically, eleven had resection, and one tumor was an incidental finding.

The more radical approach to treatment of these tumors is suggested by E. A. Graham and N. A. Womack,[9] who believe many adenomas are not recognized until they become carcinomas. They advise surgical removal since they have found repeated evidences of local invasion, involvement of regional nodes, and distant metastases. Support for this view is given by W. E. Adams, P. E. Steiner, and R. G. Block,[10] who reviewed five surgically treated cases of adenoma and found regional lymph node invasion in two instances and metastases to the liver and vertebral column in the others. S. W. Holley[11] presented thirty-eight cases of bronchial adenomas including several cylindromas. He advised lobectomy or pneumonectomy as the preferred treatment because many of the tumors are too large or have infiltrated so that they cannot be entirely removed through the bronchoscope.

Because of the wide divergence of prevailing opinion as to the best approach to the treatment of these neoplasms, a tabulation of the result in our cases was

TABLE II. ANALYSIS OF CURED OF SYMPTOM-FREE PATIENTS

AGE. (YR.)	DURATION OF ILLNESS BEFORE BRONCHOSCOPIC DIAGNOSIS*
29	6 mo.
30	5 yr.
65	7 yr.
42	1½ yr.
32	3½ yr.
31	2 yr.
13	10 mo.
57	3 yr.
35	4 mo.
21	2 yr.
32	1½ yr.
42	6 yr.
32	8 yr.
33	2½ yr.
27	2 yr.
Average 34.6	3.3 yr.

*In 22 male and 28 female patients.

Bronchoscopic examination most often reveals an occlusion of a large bronchus by a pedunculated, easily bleeding, pinkish or purplish growth covered with mucous membrane (Fig. 5). Thirty-four of the fifty patients presented this picture.

This appearance was noted in each of our fifteen successfully treated patients. In the thirty-five endoscopic failures, sixteen showed a stenosis of the bronchus with involvement of bronchial wall on initial examination.

Endoscopic therapy was instituted for all tumors that were interpreted as being of the endobronchial type. Treatment consisted in attempt at removal of the tumor through the bronchoscope and re-establishment of the patency of the lumen. The growths were grasped with bronchoscopic forceps down to and including the attachment. It was not often feasible to accomplish total removal at once, and repeated bronchoscopies were necessary.

In effecting the total removal of the tumor and with a view to prevention of recurrence, diathermy applied to the base has been a valuable adjuvant. Coagulation of the tumor base, especially in instances of local recurrence, has proved a very effective method of eradication of tumor. The most reliable proof that the neoplasm has been completely eradicated is the absence of tumor cells in biopsy specimens from the bronchial wall at the point of attachment of the neoplasm. In our early cases, bronchoscopic implantation of radium into the stump of the adenoma and external radiotherapy were employed.

All patients believed suitable for endoscopic therapy were treated in the above manner until such time as either the growth was eradicated or evidences of extrabronchial involvement were manifest. The endoscopic failures were referred for surgery.

The difficulties encountered in endoscopic removal are ordinarily not great. Troublesome bleeding, especially at early bronchoscopic treatments, may be sufficient to warrant postponement of further removal for several days.

In one instance of an intramural growth, death followed a profuse hemorrhage during bronchoscopic coagulation.

RESULTS

Fifteen, or 30 per cent, of the series of fifty patients with adenoma of the bronchus responded well to endoscopic therapy. Seven of these patients are

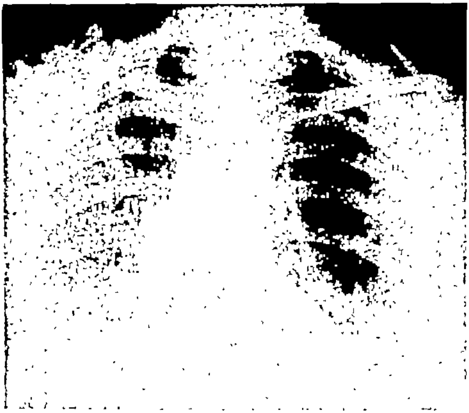


Fig. 4.—Roentgen film on expiration showing obstructive emphysema on the left with shift of trachea and mediastinum to right. On inspiration the film was normal.

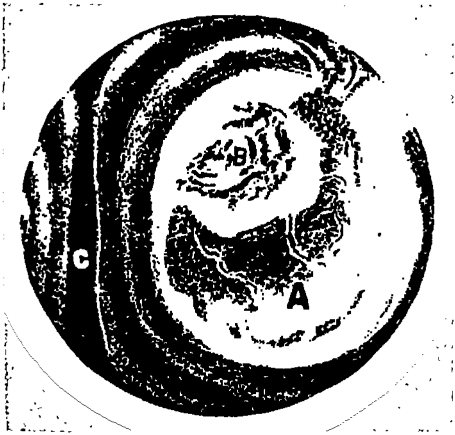
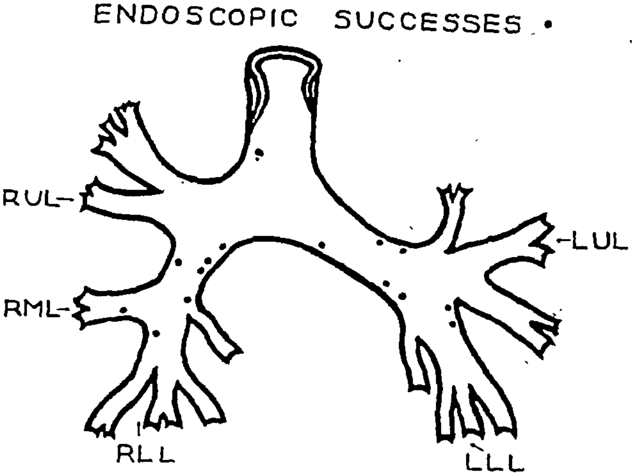


Fig. 5.—Bronchoscopic appearance of adenoma. *A*, Pedunculated adenoma of right main bronchus; *B*, infected thrombus on surface of tumor; *C*, bifurcation of the trachea.

considered completely cured and eight are symptom free. Cures are designated as patients who (1) have an absence of any symptoms referable to the bronchi and lungs, (2) have no abnormal chest findings clinically, (3) have a normal x-ray film of the chest, (4) have a widely patent bronchial lumen on bronchoscopy, and (5) show repeatedly negative bronchoscopic biopsies from the site of the tumor.

Fig. 6.



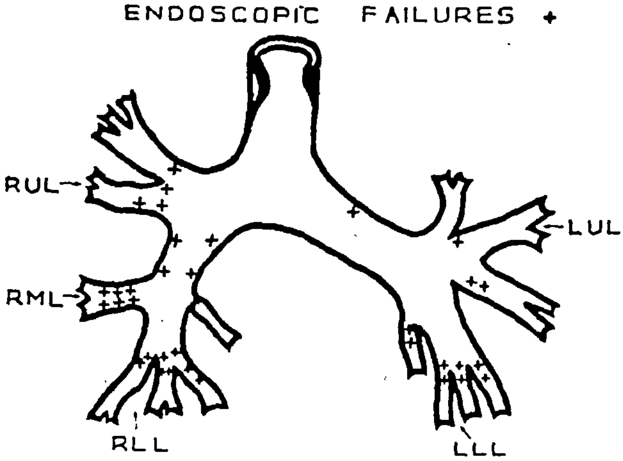


Fig. 7.

Fig. 6.—Location of origin of tumor in fifteen successful cases. Except for the one in the right middle lobe, all were in the main branch or trachea.

Fig. 7.—Location of origin of tumor in thirty-five failures. The branch bronchi are the most frequent sites of origin.

The symptom-free patients have no clinical manifestation of disease. The reason they are not considered completely cured is that they have roentgen evidence of bronchial dilatation. This residual segmental bronchiectasis is not detectable on routine chest film, but can be demonstrated by bronchography. It is of no clinical significance except that there may be a slight cough after an acute upper respiratory infection. In all other respects, these patients are as free of their disease as are those classified as cured.

An analysis of the fifteen successfully treated patients could conceivably aid in the selection of those patients who might be suitable for endoscopic therapy without benefit of surgery. Certain factors would seem to influence favorably the response to conservative treatment; namely, (1) location of the origin of the tumor, (2) duration of illness before institution of endoscopic treatment, and (3) bronchoscopic appearance. These factors will be considered separately.

(1) Location of the Origin of the Tumor.—The location of the tumor in our fifteen successfully treated patients was exclusively in the main bronchus and trachea except for the one which originated in the right middle lobe (Fig. 6). Among our thirty-five failures only five patients had tumors situated in the main bronchi, the remainder being, in order of frequency, in the lower lobes, in the upper lobes, and in the middle lobe bronchi (Fig. 7). This would indicate that the accessability of the tumor to bronchoscopic manipulation could be an important factor in determining success or failure. The anatomic surroundings of the neoplasm and the available free lumen for growth could also be a consideration favoring endobronchial confinement in the larger main bronchi. Many of the neoplasms originating in the branch bronchi often showed early evidence of intramural and extrabronchial spread (Table III). A logical inference could be that the branch bronchus neoplasms are not only less accessible for endoscopic treatment, but also show earlier evidence of intramural involvement.

TABLE III. LOCATION OF ORIGIN OF TUMORS

LOCATION	NUMBER
In Endoscopic Failures:	
Right Main Bronchus	4
Right upper lobe	4
Right middle lobe	6
Right lower lobe	9
Left main bronchus	1
Left upper lobe	3
Left lower lobe	8
In Endoscopic Successes:	
Trachea	1
Right main bronchus	6
Left main bronchus	7
Right middle lobe	1

(2) Duration of Illness Before Bronchoscopic Diagnosis.—The duration of illness before attempt at endoscopic removal in our successful series of fifteen patients was 3.3 years (Table II). If we now compare this with the duration of illness in the five main bronchus adenomas not responsive to endoscopic

TABLE IV. DURATION OF ILLNESS IN MAIN BRONCHUS ADENOMAS NOT RESPONSIVE TO ENDOSCOPIC THERAPY

LOCATION	NUMBER OF YEARS
Left main bronchus	37
Right main bronchus	25
Right main bronchus	30
Right main bronchus	7
Right main bronchus	7
Average	21.2

therapy, we find a vast difference (Table IV). The average duration in these five patients was 21.2 years. This prolonged period not only allows enough time for extrabronchial extension, but also favors the formation or irreparable suppurative disease of the lung distal to the tumor. Both of these conditions require surgery for cure.

(3) Bronchoscopic Appearance.—In all of our successful cases, a smooth globular tumor with a limited attachment was seen bronchoscopically. Stenosis of the bronchus or evidences of extrabronchial compression were seen in sixteen instances, all of which proved not amenable to endoscopic therapy. On the other hand, the finding of a globular smooth mass does not necessarily mean the tumor will permit bronchoscopic removal. The appearance of the bronchus after repeated endoscopic treatment may, however, give a clue to the possibility of cure and the advisability of continued bronchoscopy. In all of our successfully treated patients, the average number of bronchoscopies before the normal architecture of the bronchus could be visualized was three (Table V). In every instance, the normal bronchial markings, including septa and lumina of the branch bronchi, were apparent at the fifth bronchoscopy. Considering that treatment can be given at five-day intervals, it does not appear too protracted a trial period before abandoning attempts at conservative cure. The number of treatments required before the tumor was completely removed and the biopsy reported consistently negative was found to be between three and eight (Table V). The inability to eradicate the tumor completely and visualize the normal architecture of the bronchus after a fair trial period is an indication for surgical intervention.

TABLE V

NUMBER OF BRONCHOSCOPIES BEFORE NORMAL ARCHITECTURE OF BRONCHUS WAS VISUALIZED	NUMBER OF TREATMENTS BEFORE BRONCHOSCOPIC BIOPSY SHOWED NO TUMOR
5	7
2	4
4	5
3	4
2	4
2	5
2	4
3	8
2	4
2	4
3	8
2	4
3	4
3	3
5	6

While no hard and fast rules can be made as to a time limit for cessation of endoscopic treatment, certain findings militate against further treatment. The persistance of a dense shadow in the lung after the endobronchial portion of the tumor has been eradicated is significant. Such densities may well represent either outlines of the tumor mass itself, or adjacent lymph nodes locally invaded by the tumor.

Recurrent hemoptyses and continued exacerbations of the lung suppuration point to the need for surgery. It is important to appreciate that the bronchiectasis distal to the tumor may occasionally be reversible if the obstruction is promptly relieved. Such bronchiectasia seems to run a much more benign course than that of ordinary bronchiectasis following suppurative bronchopneumonia. The need for surgical treatment of lung suppuration itself after eradication of the tumor endobronchially is not frequent.

Local endobronchial recurrence of the tumor without evidence of peribronchial spread is not necessarily an indication for surgery. Such local recurrence should be interpreted more as evidence of incomplete eradication of the slowly growing tumor rather than as manifestation of malignancy and an indication for surgery. In two of our successful cases, early recurrence of the tumor was detected bronchoscopically and treated by coagulation. The patients have been symptom-free for a period of ten and five years respectively (Table VI).

TABLE VI. DURATION OF SYMPTOM-FREE FOLLOW-UP PERIOD, BRONCHOSCOPY AND BIOPSY CONSISTENTLY NEGATIVE

RECURRENCE	NUMBER OF YEARS
	5
	14
	7
Local, in 1937, after 2 coagulations remained negative	10
	2½
	6
	14
	1½
	10
	7
Local, in 1942, after coagulations remained negative	5
	1
	4
	6
	10

It is imperative that all patients with adenoma be bronchoscoped occasionally so that biopsies can be taken of any suspicious areas, and the absence of tumor cells proved microscopically.

The patients have been followed from one to fourteen years. Many feel so well that they refuse to return for endoscopy. Only those who consistently return for observation are here included.

SUMMARY

Fifty cases of endoscopically proved adenoma of the bronchus are reviewed. Fifteen, or 30 per cent, of these remain completely cured or symptom-free following bronchoscopic removal, usually with coagulation of base.

Pedunculated smooth globular tumors originating in the main bronchi seem most suitable for endoscopic removal provided the diagnosis is established early. Tumors situated in the branch bronchi are distinctly not favorable, both because they are less accessible and show a tendency to spread intramurally.

In this series, the normal architecture of the bronchus was discernible after the fifth bronchoscopy. The persistence of the tumor as suggested by bronchial wall involvement and proved by a consistently positive biopsy suggests extrabronchial spread and requires surgical removal. With the development of a relatively safe technique for the removal of a lung lobe, extrabronchial adenomas are now being treated in this manner with increasing frequency.

Unlike carcinoma of the bronchus, untreated patients with adenoma have a life expectancy of ten to twenty years. In an individual of advancing years, therefore, the need for lobectomy or pneumonectomy is not nearly as urgent as in instances of truly malignant neoplasms.

REFERENCES

1. Kramer, R., and Som, M. L.: Further Study of Adenoma of the Bronchus, Ann. Otol., Rhin. & Laryn. 44: 861-878, 1935.
2. Wessler, H., and Rabin, C. B.: Benign Tumors of the Bronchus, Am. J. M. Sc. 185: 164-180, 1932.
3. Rabin, C. B., and Moolten, S.: Pathology of Adenoma of the Bronchus, Association of American Pathology and Bacteriology, Annual Meeting, 1935.
4. Jackson, C. L., Konzelman, F. W., and Norris, C. M.: Bronchial Adenoma, J. THORACIC SURG. 14: 98-105, 1945.
5. Adams, R.: Primary Lung Tumors, J. A. M. A. 130: 547-553, 1946.
6. McDonald, J. R.: Symposium on Adenomas and Cylindromas, Pathologic Aspects, Proc. Staff Meet. Mayo Clin. 21: 416-426, 1946.
7. Tinney, W. S.: Symposium on Adenomas and Cylindromas: Diagnostic Aspects and Bronchoscopic Treatment, Proc. Staff Meet. Mayo Clin. 21: 414-416, 1946.
8. Adams, R.: Discussion of So-Called Adenoma of the Bronchus, J. THORACIC SURG. 14: 119, 1945.
9. Graham, E. A., and Womack, N. A.: Problem of So-Called Bronchial Adenoma, J. THORACIC SURG. 14: 106-119, 1945.
10. Adams, W. E., Steiner, P. E., and Block, R. G.: Malignant Adenoma of the Lung, Surgery 11: 503-526, 1942.
11. Holley, S. W., Major, M. C.: Bronchial Adenomas, Mil. Surgeon, 99: 528-554, 1946.
12. Kramer, R., and Som, M. L.: Cylindroma of the Upper Air Passages, Arch. Otolaryng. 29: 356-370, 1939.

CONTRALATERAL SPONTANEOUS PNEUMOTHORAX FOLLOWING LOBECTOMY

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SERIOUS complications following pulmonary resection are becoming more and more infrequent with a resulting decrease in both morbidity and mortality which, in competent hands, predicts a safety of operation which will compare very favorably with any surgical procedure of parallel magnitude. Suppuration, bronchial fistula, and hemorrhage have been so reduced in importance as a complication after lobectomy or pneumonectomy that one actually encounters such setbacks but very rarely. However, unusual complications do occur from time to time and the recording of such an event is the purpose of this case report.

In brief, this an instance of persistent right spontaneous pneumothorax which occurred on the third day after the left lower lobe had been resected for bronchiectasis. The collapse of the right lung was complete, leaving virtually a single functioning pulmonary lobe, the remaining upper lobe on the left. Furthermore, the pneumothorax failed to respond to conservative measures and became so marked nineteen days after onset that right thoracotomy was necessary and the leaking emphysematous bleb was excised. Thereafter, recovery was rapid and complete.

CASE REPORT

D. L., a white man, aged 23 years, was admitted to the hospital on June 14, 1947, with complaints which included productive cough, anorexia, and loss of weight. The history indicated that the pulmonary complaints had followed a bilateral pneumonitis in 1942 for which he spent fifty-five days in an Army Hospital. In May, 1946, weight loss began and in October, 1946, the sputum became more abundant and fetid in odor. Upon admission the loss of weight had totaled fifty pounds in thirteen months. One month before entering the hospital he began to experience slight hemoptyses, chilliness, night sweats, and intermittent episodes of hyperpyrexia.

Clinical studies revealed that there were abnormal physical signs over the left lower chest most significant of which was the constant finding of râles upon auscultation. Further observations included a daily sputum production of 180 c.c. of thick, purulent secretion. Repeated examinations of this material were negative for acid-fast bacilli and cultures yielded a mixed flora. The intradermal tests with both strengths purified protein derivative were negative. A complete blood count indicated a moderate secondary anemia with a red cell count of 3,700,000 and a hemoglobin of 12 Gm., or 72 per cent.

Bronchography revealed bronchiectasis limited to the left lower lobe (Fig. 1). Bronchoscopy showed that a great deal of purulent secretion arose from the left lower lobe bronchus.

Preparatory therapy consisted of rest, sedation, high caloric intake, iron therapy, supplementary vitamin administration, postural drainage, and penicillin aerosol inhalations.

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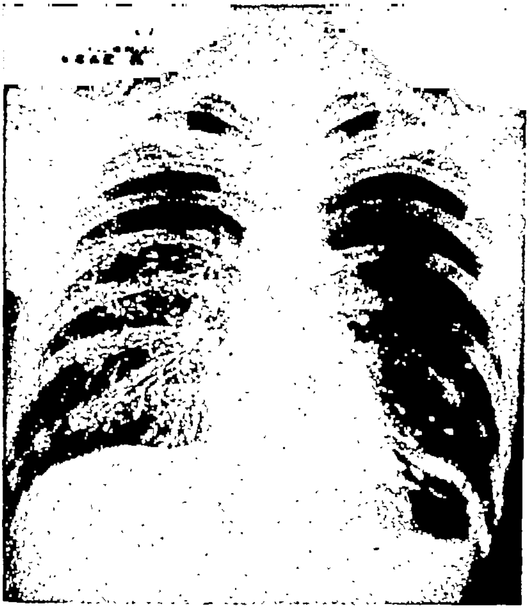

Fig. 1.

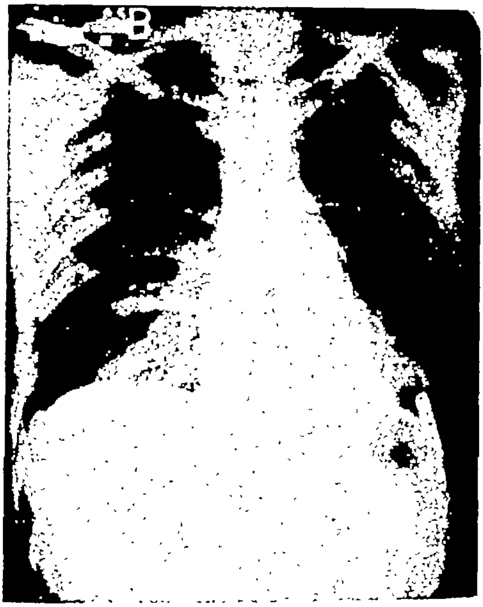

Fig. 2.

Fig. 1.—Bronchogram which reveals bronchiectasis of the left lower lobe.

Fig. 2.—Portable film of the chest taken Aug. 25, 1947, two days after resection of the left lower lobe.

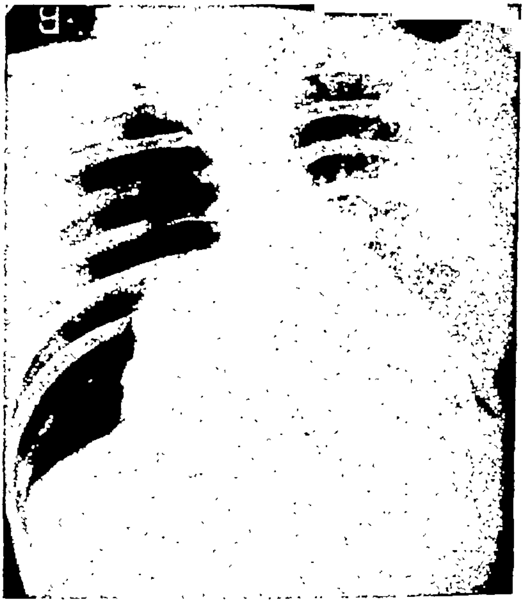

Fig. 3.—Portable film of the chest taken Aug. 29, 1947, on the third day after resection of the left lower lobe. There is a right spontaneous pneumothorax with complete collapse of the lung.

Clinical improvement followed this regimen and he was considered to have achieved maximum effect by Aug. 20, 1947. Consequently, left lower lobe resection was performed on Aug. 26, 1947, employing individual ligation technique for the vessels with careful closure and burial of the bronchial stump. The immediate postoperative course was uneventful and forty-eight hours after operation a chest x-ray film was taken as a routine matter (Fig. 2) whereby complete expansion of the remaining left upper lobe was established. During the following twelve hours the patient coughed a great deal and finally began to complain of moderate dyspnea. His color was good and the pulse rate was 104, however the respiratory rate was 35 per minute in an oxygen tent and a second bedside chest roentgenogram was taken (Fig. 3, Aug. 29, 1947), which revealed pneumothorax on the right side with complete collapse of the right lung.

Following this revelation 1,500 c.c. of air were aspirated from the right pleural space and eight hours later an additional 1,700 c.c. of air were removed. Expansion of the lung became complete within seventy-two hours. The patient was then permitted to follow a normal postoperative routine and was allowed out of bed on Sept. 4, 1947.

On Sept. 11, 1947, the right spontaneous pneumothorax recurred with complete collapse of the right lung as on the first occasion. Aspiration of 8,700 c.c. of air over a fifty-two hour period was followed by complete expansion of the lung. However, on Sept. 19, 1947, the spontaneous pneumothorax recurred once more and repeated aspirations of air totaling 22,500 c.c. over seven hours failed to expand the right lung. It was obvious that air was leaking into the pleural space as fast as it was being removed. Consequently, a right thoracotomy was performed at 6 P.M. on Sept. 19, 1947, twenty-three days after removal of the left lower lobe. The right lung was found to be completely collapsed. There was a cluster of six emphysematous blebs on the surface of the apex of the upper lobe, one of which was clearly shown to be leaking air continuously. This group of blebs was excised, the surface incision in the apex of the lung was repaired by suture, the lung was expanded, and the chest wound was closed. A single intercostal catheter was employed under water seal trap but this was removed after seventy-two hours.

The postoperative convalescence was rapid and uneventful. The patient was ambulatory on the fifth day after thoracotomy and was released from the hospital on the eighteenth day after operation. There has been no recurrence of spontaneous pneumothorax and he is free of the symptoms of bronchiectasis as well.

SUMMARY

1. A case history is presented which describes the occurrence of a right spontaneous pneumothorax on the third day after resection of the left lower lobe.

2. Despite the complete collapse of the right lung and the absence of the left lower lobe, the patient manifested only moderate dyspnea without cyanosis. The total functioning pulmonary area was confined to the single left upper lobe.

3. Tension pneumothorax with mediastinal shift to the opposite side did not occur. Had it been present, the respiratory embarrassment would undoubtedly have been much more marked.

4. Surgical intervention became necessary to control the right spontaneous pneumothorax which was found to be due to a leaking emphysematous bleb on the surface of the apex of the lung.

PRIMARY CHONDROSARCOMA OF THE LUNG

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CHONDROSARCOMA is a relatively uncommon tumor, and is exceedingly rare in the lung. In the case to be described the tumor appeared to be confined to the pulmonary artery and its branches. Compared to other reported chondrosarcomas it seemed to be unique in this respect.

CASE REPORT

History.—The patient, a 41-year-old white housewife, was first seen by one of us (J. E. T.) on Dec. 21, 1945. She had been well until June, 1944, when she noted the gradual onset of fatiguability, nervousness, anorexia, transient ankle edema, weight loss from 115 to 105 pounds, and dyspnea, tachycardia, and palpitation on moderate exertion. There was also a feeling of fullness and soreness in the left lower chest anterolaterally, made worse by exertion. Neither orthopnea nor nocturnal dyspnea was present. Examination by a physician in June, 1944, was said to have shown cardiac enlargement and a murmur. Rest was advised. She regained six pounds during August, 1944, but the complaints persisted. In September, 1945, she developed a nonproductive cough and symptoms of mild sinusitis. Early in November, 1945, she had a sudden attack of dyspnea on turning around quickly and was unconscious for five minutes. A week later there was a three-day episode of persistent nonpleuritic pain in the left lower chest posteriorly. At that time she began to lose weight again. The nonproductive cough persisted, and dyspnea and palpitation were present on slight exertion.

The patient had pneumonia in 1912 and 1913; an appendectomy and removal of a "tumor" of the left ovary in 1929; a spontaneous abortion in 1935 and a normal delivery in 1937; and pleurisy on the left side for one week in 1940. The last menstrual period was in September, 1945. Her father had had heart disease and her mother hypertension.

Physical Examination.—On Dec. 21, 1945, inspection revealed the patient to be pale, thin, and slightly dyspneic at rest. Pulse rate was 92, respiratory rate 30, blood pressure 136/64, temperature 98.6° F., and weight 103 pounds. The abnormal physical findings were limited to the cardiorespiratory system and consisted of: impaired resonance to percussion, weak breath sounds, and resonating râles after cough over the lower half of the left chest posteriorly; slight deviation of the heart and trachea to the left; very frequent extrasystoles; a loud pulmonic second sound; and a systolic murmur heard over each of the valve areas, that at the aortic area being transmitted into the neck. The neck veins were not distended, and no peripheral edema or liver enlargement was evident.

A roentgenogram of the chest made in June, 1944, showed some retraction of the heart to the left with prominence of the area of the pulmonary conus. There was a small density in the left lung adjacent to the mediastinum at the level of the left sixth posterior interspace. In December, 1945 (Fig. 1, *A*) this density was larger and there was a prominent mass posterior to the heart in the plane of the sixth to the ninth ribs posteriorly. The left leaf of the diaphragm was a little higher than the right, but the aeration of the left lung was good. The right lung appeared normal.

An electrocardiogram had been made on Dec. 11, 1945, by the referring physician.* He reported that it showed right axis deviation, a diphasic T wave in the second lead, and an isoelectric T wave in the precordial lead. Routine examination of the blood and urine was normal, and the blood Kahn reaction was negative.

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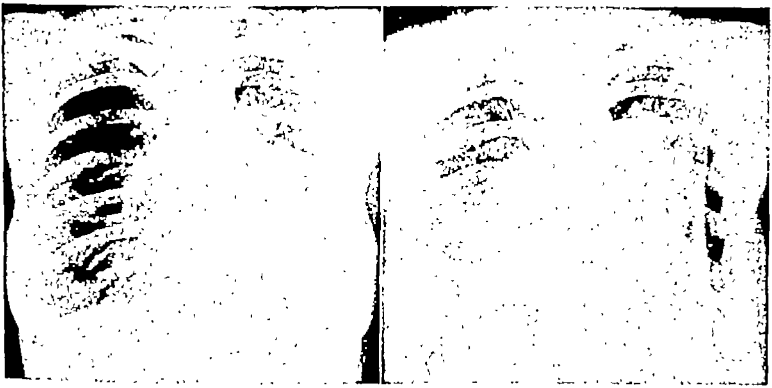
At bronchoscopy on Dec. 22, 1945, the left main stem bronchus and its devisions were seen to be displaced posteriorly as if by a mass lying anteriorly. No other abnormality was found.

It was concluded that the patient had a tumor of the left lung of undetermined type and a heart lesion of congenital or rheumatic origin. Because of the respiratory insufficiency, thoracoscopy following the institution of a left pneumothorax rather than an immediate exploratory thoracotomy was advised.

Clinical Course.—For various reasons the patient did not return for hospitalization until Feb. 17, 1946. Examination at this time revealed a rough presystolic and systolic mitral murmur transmitted to the left axilla. Systolic murmurs were also heard over the other valve areas. The liver margin was palpable 4 cm. below the right costal margin, and moderate persistent ankle edema was present. Fluoroscopy showed the densities near the left hilus to be somewhat larger. The right hilar shadow was enlarged and pulsated noticeably.



A. *B.*

Fig. 1.—*A*, Dec. 11, 1945, densities near the left hilus. Shift of the heart to left with prominence in area of the pulmonary conus.

B, Feb. 21, 1946, bilateral hilar densities and infiltration in the right second anterior interspace; artificial pneumothorax, left.

In twenty-four hours she produced 15 c.c. of mucopurulent sputum which was negative for tubercle bacilli on concentration. The voided urine contained 130 mg. per cent albumin, occasional hyaline and many granular casts, a few erythrocytes, and many leucocytes per high-power field. A routine blood count and sedimentation rate were within normal limits.

Digitalization was begun on February 18 because of apparent right heart failure. Left pneumothorax was instituted on the same day. Eight hours later she became quite dyspneic and cyanotic, and air was withdrawn once. Fluoroscopy next day revealed a 20 per cent collapse of the left lung with apical adhesions. Small pneumothorax refills were given on February 19 and 20. Oxygen therapy was given intermittently because of dyspnea. A roentgenogram of the chest taken on February 21 showed considerable increase in the right hilar shadow with a fuzzy area of infiltration 2 cm. in diameter in the right upper lung field. The densities near the left hilus were larger than in the previous films. A 20 per cent collapse of the lower two-thirds of the left lung was present (Fig. 1, *B*).

It was decided to forego thoracoscopy and to abandon the pneumothorax because of the patient's poor condition and because it was feared that the tumor might already have metastasized to the right lung. After 350 c.c. of air had been aspirated from the left pleural cavity on February 25 she become more cyanotic and dyspneic. Six hours later signs of marked peripheral vascular collapse were present. Oxygen therapy and plasma given intravenously were of temporary benefit only, and she died the same day.

Pertinent Gross Autopsy Findings (Fig. 2).—The heart, which weighed 420 grams, showed moderate dilatation of the right atrium and ventricle with hypertrophy of the latter. No gross valvular changes were present. A tumor in the pulmonary artery extended to within 1 cm. of the pulmonary valve, where together with a small thrombus it completely occluded the vessel. The wall of the pulmonary artery contained a few small arteriosclerotic plaques, and there was moderate thickening of its intima.

Posteriorly at the level of the left fifth rib the parietal and visceral pleural surfaces were fused. A few easily separated adhesions were present over other areas of both lungs. Approximately 200 c.c. of clear pink fluid and an estimated 200 c.c. of air were present in the left pleural cavity. The left lung weighed 540 grams and the right lung 750 grams. The left lung was small and firm. On the medial surface of the left lung below the hilus a white tumor was seen through the pleura. A frontal section through the left lung revealed, near the hilus, a firm white tumor mass measuring 6 by 10 cm. This mass extended into and almost filled the left pulmonary artery, the main pulmonary artery, the primary branches of the right pulmonary artery, and the smaller branches to the right apex. Within the left lung the growth was lobulated and in most places it was sharply demarcated from the compressed reddish-brown lung. The tumor was firm and grated slightly when cut. For the most part it was definitely bounded by arterial walls, and dissected portions of the tumor resembled casts of small branching blood vessels. No connection was found between the intra-arterial tumor and any bronchus, although the left lower lobe bronchus was moderately distorted and compressed. Within the main pulmonary artery the tumor was soft, friable, and fungating. No gross changes were noted in the hilar or mediastinal lymph nodes, except for two glands in the right hilus which had undergone calcification. The right lung was crepitant and appeared normal externally. On section there was tumor involvement in the upper portion as described previously.

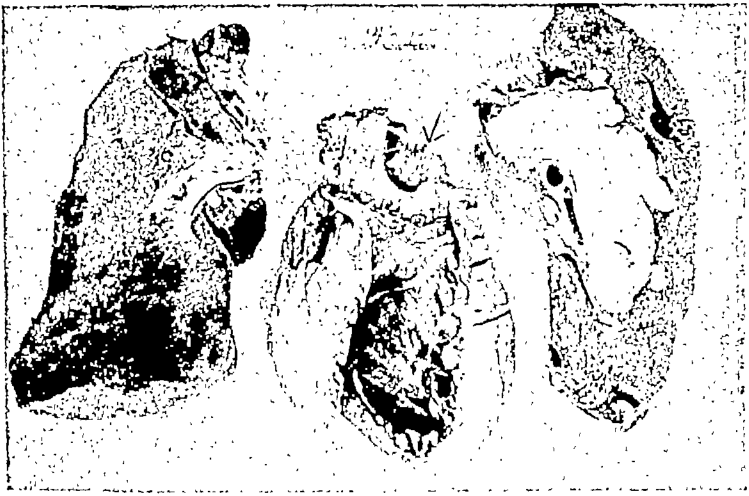
The liver weighed 1,330 grams and showed changes typical of chronic passive hyperemia. Examination of the other organs and of the bones and joints revealed no evidence of primary or metastatic malignancy.

Histopathology.—The portion of the tumor within the main pulmonary artery resembled adult cartilage (Fig. 3, *A*), except that calcification and necrosis were widespread, and there was increased cellularity with plump and occasionally double nuclei. Sections from the tumor extended to the right apex (Fig. 3, *B*), however, revealed cartilaginous islands in a stroma of undifferentiated mesenchymal cells with pale-staining cytoplasm, and nuclei which were round, oval, or occasionally spindle-shaped. Areas of necrosis and myxomatous degeneration were widespread. The least differentiated portions (Fig. 3, *C*) were found within the main tumor mass in the left lung where there was no resemblance to cartilage. The cells here had much larger nuclei, moderately hyperchromatic and often spindle-shaped, but only an occasional mitotic figure was present.

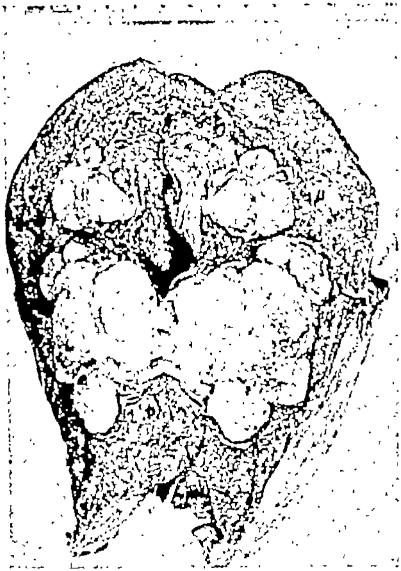
In one section several small spicules of bone not associated with cartilage were seen in the malignant-appearing stroma. Many vascular channels lined with either endothelial or tumor cells were present. For the most part the tumor was bounded by arterial wall (Fig. 3, *D*); in other places the boundary was too thin to identify it as such. No clefts lined with epithelium, commonly seen in hamartomas of the lung,[2] were seen. Wilder's silver stain revealed a fine reticulum throughout the less differentiated portions of the tumor. A whorl-like arrangement of the cells was demonstrated, and tortuous lymph or blood vascular channels were sharply outlined.

Changes in the left lung outside of the tumor consisted of patchy atelectasis, chronic passive hyperemia, and edema. Apart from the neoplasm no significant pathology was found in the right lung.

The liver displayed the moderate central lobule necrosis of passive hyperemia. The microscopic findings in the remainder of the organs were normal or noncontributory to this report.



A.



B.

Fig. 2.—*A*, frontal sections through both lungs; heart with right ventricle and pulmonary artery opened to expose tumor (arrow). Note that the tumor follows distribution of pulmonary arteries. *B*, Section through unfixed left lung showing bulging chondrosarcomatous masses.

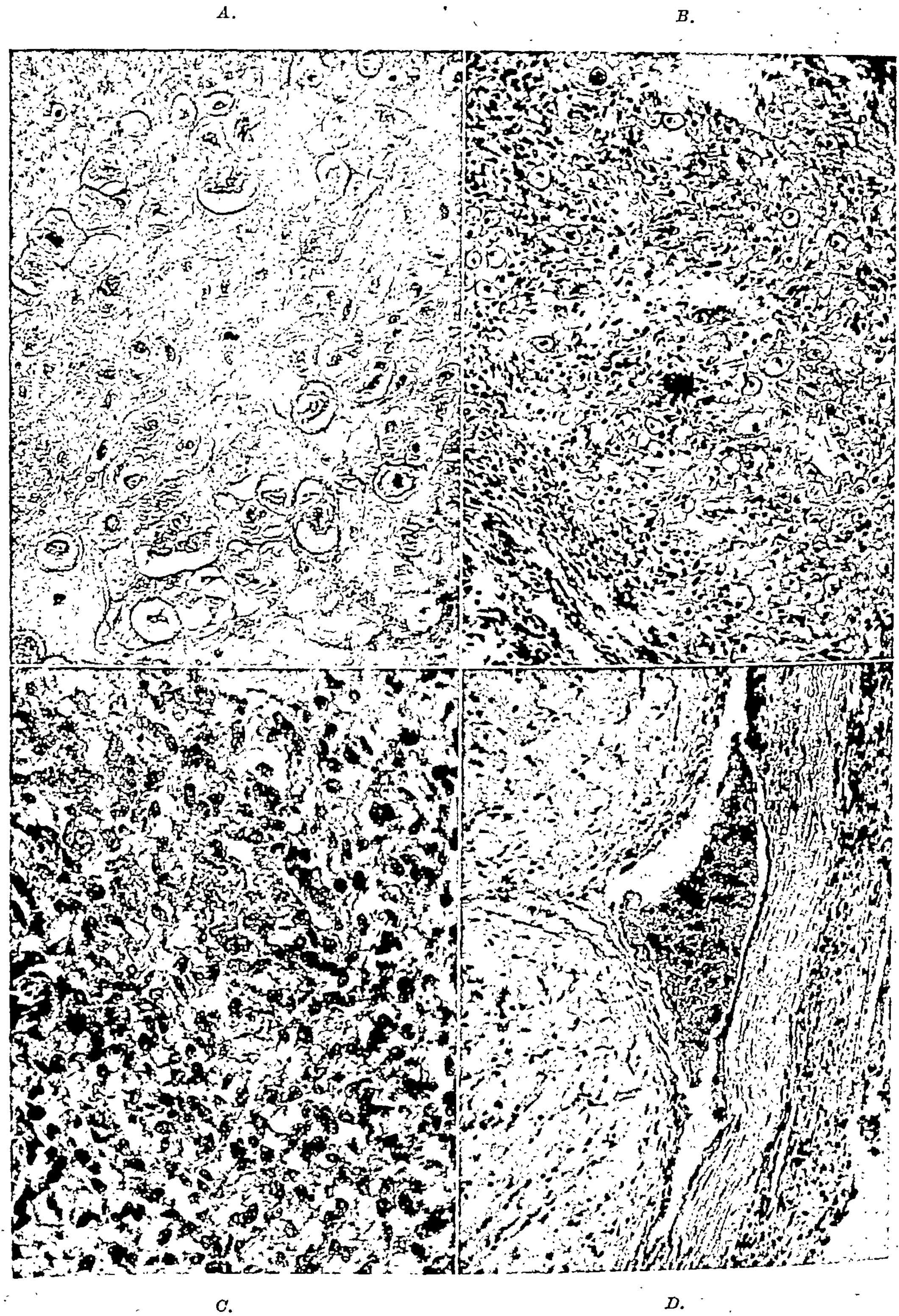


Fig. 3.—Photomicrographs of tumor. *A*, Within main pulmonary artery (×130); here the chondrosarcoma is well differentiated. *B*, Within branch of pulmonary artery to right apex (×130); both differentiated and undifferentiated chondromatous cells are seen in this field. *C*, From main tumor mass in left lung (×275); only chondroblasts occur here. *D*, Section through pulmonary artery containing tumor and thrombus (×130).

DISCUSSION

Greenspan[1] in 1933 reported a case of "primary osteoid chondrosarcoma" of the lung, which he believed to be the first reported in the literature, although he stated that a case reported by Roe[3] in 1866 had similar gross anatomic characteristics. Greenspan was able to demonstrate marked narrowing of the lumen of a bronchus and infiltration of its wall by tumor tissue. He described osteoid elements in the tumor and metastatic tumor nodules in the pericardium, pleurae, and myocardium. None of these features was present in our case, in which the tumor seemed to be limited to the pulmonary artery and its branches. The following points of similarity do exist: (1) invasion of the pulmonary artery producing cor pulmonale, (2) similarity in gross appearance, (3) pleomorphism evident microscopically, (4) no clinical or autopsy evidence of a primary source of a neoplasm outside the lung, and (5) absence of metastases outside the thorax.

Greenspan's case obviously can be regarded as malignant and therefore as a chondrosarcoma, rather than as a benign chondroma, simply on the basis of the demonstrable metastases. The case herewith reported exhibited gross malignant characteristics only by its having advanced through the pulmonary arterial system, no discontinuous metastases having occurred. It would therefore seem advisable to support the diagnosis of malignancy by histopathologic evidence. In 1940 Ewing[4] stated that "while in general the more cellular and softer tumors, as myxochondroma, are the more malignant, both clinical and histological features should be regarded in applying the term chondrosarcoma." Lichenstein and Jaffe[5] in 1943 presented the first satisfactory study of the transition stages between benign and malignant cartilage tumors based on histologic features alone. It is true that their study dealt only with cartilage tumors arising from cartilaginous elements of bone; however, it seems logical to apply the same criteria in judging the malignancy of any cartilage tumor.

Lichenstein and Jaffe stated that "a cartilaginous tumor should no longer be regarded as benign if, when viable and not heavily non-calcified areas are examined, it shows, even in scattered fields: (1) many cells with plump nuclei, (2) any giant cartilage cells with large single or multiple nuclei or with clumps of chromatin." The microscopic examination in our case fulfills these criteria. In addition pleomorphism was marked, the cellular picture ranging from completely undifferentiated spindle-shaped cells to mature cartilage cells. In fact, the tumor affords an excellent study of the histogenesis of cartilage, exhibiting as it does all phases of cartilage formation.

Greenspan's case of chondrosarcoma primary in the lung was the only one which could be found in the literature. However, reports of nineteen cases of chondrosarcoma arising in a distant bone and metastasizing to the lung were collected by Castren[6] in 1931. In several of these there was uninterrupted extension from an obvious primary site through the inferior vena cava, heart, and pulmonary arteries.[4, 6] Grossly and histologically the pulmonary metastases in this latter group were quite similar to the primary tumor reported in this paper. Chondrosarcomas may arise from the ribs and sternum but rarely invade the lung secondarily.

Six cases of primary sarcoma of the pulmonary artery with metastases to the heart and lungs were collected recently by Durgin and Ingleby.[7] However, all these tumors appeared to arise from the intima or muscularis, and none was cartilaginous.

At least ninety-six primary benign cartilage tumors,[2] usually designated as "hamartomas" in the recent literature, have been reported. They represent overgrowths of the epithelial and mesothelial elements normally found in bronchi, the epithelial component appearing as clefts lined with epithelium (usually ciliated), the mesothelial element as adult cartilage. None of these tumors has been noted within pulmonary vessels.

Simon and Ballon[8] recently reported an unusual case of hamartoma of the lung which showed microscopic evidences of malignancy much like those described in our case, although there were no metastases and no invasion of pulmonary vessels. This tumor, unlike ours, contained definite clefts lined with epithelium, a fact which makes its origin from a hamartoma quite likely.

We are at a loss to account for the exact origin of the tumor described in this communication. It may have arisen in a bronchus and then invaded the pulmonary arterial system, as did the tumor reported by Greenspan, although such a sequence could not be verified by careful dissection or by study of the microsections. Only one adequately described hamartoma showing definite malignant characteristics has so far been reported.[8] The rarity of such a picture together with the absence of epithelial clefts in our tumor are strongly against its development from a hamartoma. If it arose from a distant chondrosarcoma of bone which was overlooked at autopsy, it would still be without precedent, since such previously reported tumors all showed an obvious primary site. It also seems farfetched to postulate an origin in the wall of the pulmonary artery.

Clinical Comment.—The onset of this patient's signs and symptoms occurred about twenty months before death. Presumably the tumor first gradually filled the left pulmonary artery causing right axis deviation and a loud pulmonic second sound. The roentgenograms suggest that the spread to the right pulmonary vessels occurred only in the last month or two of life, at which time the right heart strain rapidly became more pronounced. Right heart failure was well marked in the last week, and the terminal event was thrombosis in the remaining lumen of the main pulmonary artery.

The presence of a tumor within the pulmonary vessels is seldom suspected during life because of the rarity of such an occurrence. The inclination is to attribute the cardiac signs and symptoms to the familiar effects resulting from myocardial or valvular disease. It is doubtful if a tumor in the pulmonary artery large enough to produce cardiac strain would be amenable to surgical removal.

SUMMARY

A unique case of primary chondrosarcoma in the lung filling both pulmonary arteries is reported. A discussion of the factors concerned in the pathologic diagnosis is given, and the literature relating to cartilage tumors involving the lung is briefly reviewed.

The advice of Dr. Vinton D. Sneeden and Dr. Warren C. Hunter of the Department of Pathology and of Dr. William S. Conklin of the Division of Thoracic Surgery of the University of Oregon Medical School is gratefully acknowledged.

REFERENCES

1. Greenspan, E. B.: Primary Osteoid Chondrosarcoma of the Lung: Report of a Case, Am. J. Cancer 18: 603, 1933.
2. McDonald, John R., Harrington, Stuart W., and Clagett, O. Theron: Hamartoma (Often Called Chondroma of the Lung), J. THORACIC SURG. 14: 128, 1945.
3. Roe, H.: A Case of Malignant Tumor at the Root of the Left Lung, Lancet 2: 723, 1866.
4. Ewing, J.: Neoplastic Diseases, ed. 4, Philadelphia, 1940, W. B. Saunders Company.
5. Lichenstein, Louis, and Jaffe, Henry L.: Chondrosarcoma of Bone, Am. J. Path. 19: 553, 1943.
6. Castren, H.: Zur Kenntnis der metastasenbildenden Chondrome, acta Soc. med. fenn. duodecim 15: 1, 1931.
7. Durgin, B., and Ingleby, H.: Primary Sarcoma of Pulmonary Artery, Clinics 5: 182, 1946.
8. Simon, M. A., and Ballon, H. C.: An Unusual Hamartoma (So-Called Chondroma of the Lung), J. THORACIC SURG. 16: 379, 1947.

LOBECTOMY IN COCCIDIOIDOMYCOSIS

REPORT OF TWO CASES

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SINCE the advent of World War II, coccidioidomycosis has been seen in all sections of the country. The high incidence of this infection is due to the fact that during the war many service men were stationed in or traveled through endemic areas of coccidioidomycosis in the San Joaquin Valley, central and other parts of California, Arizona, and Texas. These men were exposed to the chlamydospores of *Coccidioides immitis.* Many contracted the disease and were treated, while others had asymptomatic primary disease and were not treated. Patients in this latter classification are now being admitted with secondary coccidioidal cavities. This paper contains reports of two such cases which we would like to discuss briefly.

In reviewing the literature, we were able to find reports of only two cases of coccidioidomycosis in which lobectomy was done. Peers, Holman, and Smith[1] reported a case in 1942 in which a right upper lobectomy was performed for a solitary cavity. Their indication for surgery was fear that the patient was in danger of dissemination of the infection throughout the rest of the body. Pneumothorax was tried first, but this did not close the cavity and sputum and gastric washings remained positive for *Coccidioides immitis.* A right upper lobectomy was then done, followed by a thoracoplasty.

The second case was reported to one of us (J. A. M.) by Blades of Washington, D. C.[2] Blades did a lobectomy at Walter Reed Hospital for a single large cavity in the left upper lobe which had been present for two years. The indication in this case was hemoptysis. An excellent result was obtained.

CASE REPORTS

CASE 1.—H. W., a 25-year-old Negro man served in the army from Jan. 21, 1943, until Jan. 13, 1946. During part of this service he was stationed in the desert area of California, but did not manifest any symptoms of coccidioidomycosis at any time while in the army.

At the separation center, Camp Blanding, Florida, roentgenologic examination Jan. 13, 1946, revealed a cavity in the lower lobe of the right lung, although he had had no previous symptoms (see Fig. 1). A diagnosis of "tuberculosis, pulmonary, chronic, moderately advanced, active" was made and the patient was transferred to Moore General Hospital, Swannanoa, N. C., March 7, 1946, for treatment.

On admission he was asymptomatic, had a good appetite, and had lost no weight. On physical examination he appeared well developed, well nourished, and did not seem acutely or chronically ill. Examination of the lungs was negative. No râles were present. Temperature was normal, blood pressure was 110 systolic, 65 diastolic, and pulse 78 per minute. There was no familial history of tuberculosis.

From the Department of Medicine and Surgery, Veterans Administration Hospital, Oteen, North Carolina; published with permission of the Chief Medical Officer, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or conclusions drawn by the authors.

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Laboratory findings on admission were as follows: total erythrocyte count 4,780,000, hemoglobin 91 per cent, total leucocyte count 8,700, with 50 polymorphonuclears, 38 lymphocytes, 8 monocytes, 3 eosinophiles, and 1 basophile. The blood sedimentation rate (Wintrobe, corrected) was 7 mm. per hour. Urinalysis showed acid reaction, specific gravity 1.018, negative for albumin and sugar, and negative on microscopic examination. The vital capacity was 3,500 cubic centimeters. Serology (Kahn) was negative. Seven direct sputum smears, four seventy two-hour sputum concentrates, two sputum cultures, and a guinea pig inoculation were negative for acid-fast bacilli.

Bronchoscopies on June 24, 1946, Aug. 13, 1946, and Jan. 31, 1947, were negative and cultures taken for acid-fast bacilli and *Coccidioides immitis* were negative. He had a positive (+15) skin test for tuberculosis in the first strength, Coccidioides skin test was negative in the 1:1,000 dilution and positive (+10) in the 1:10 dilution. Histoplasmosis skin test was negative in the 1:1,000 dilution and positive (+5) in the 1:10 dilution.

In June, 1946, blood was sent to the Stanford University School of Medicine for serological test for coccidioidomycosis. Complement fixation tests were reported as negative.

The cavity in the right lower lobe increased in size (Fig. 2) four and one-half months after admission. There was no infiltration around the cavity. The left lung was clear. Lipiodol studies revealed only one cavity present in the right lower lobe.

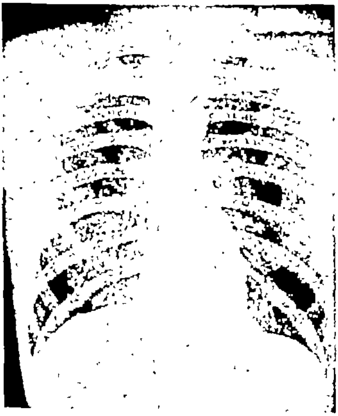

Fig. 1.

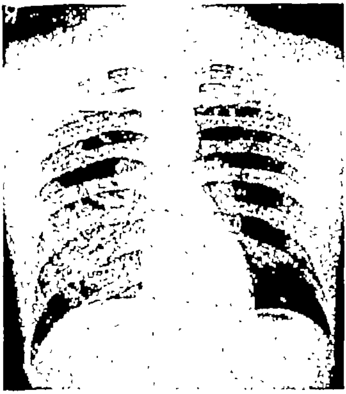

Fig. 2.

Fig. 1 (Case 1).—X-ray film taken Jan. 31, 1946, at separation center, Camp Blanding, Fla., showing single thin-walled cavity in upper portion of right lower lobe. Note absence of other pulmonary disease.

Fig. 2 (Case 1).—X-ray film taken June 14, 1946, at Moore General Hospital, Swannanoa, N. C., showing increase in size of cavity in right lower lobe during four and one-half months of bed rest.

A right phreniclasia was done Feb. 13, 1947, in order to collapse the cavity but no decrease in size was noted. In view of the negative tuberculin findings, a diagnosis of lung cyst, right lower lobe, was made and the patient was transferred to the Veterans Administration Hospital at Oteen, N. C., April 7, 1947, for surgery.

At this time his only complaint was occasional pain in the right posterior chest on deep breathing. He was afebrile and his weight remained at a constant level. On April 4, 16, 22, and 24 (fifteen months after the cavity was discovered) his sputum was positive by smear and culture for *Coccidioides immitis.* X-ray examination now revealed a thin-walled cavity in the posterior portion of the right upper lobe near the apex. In view of the positive

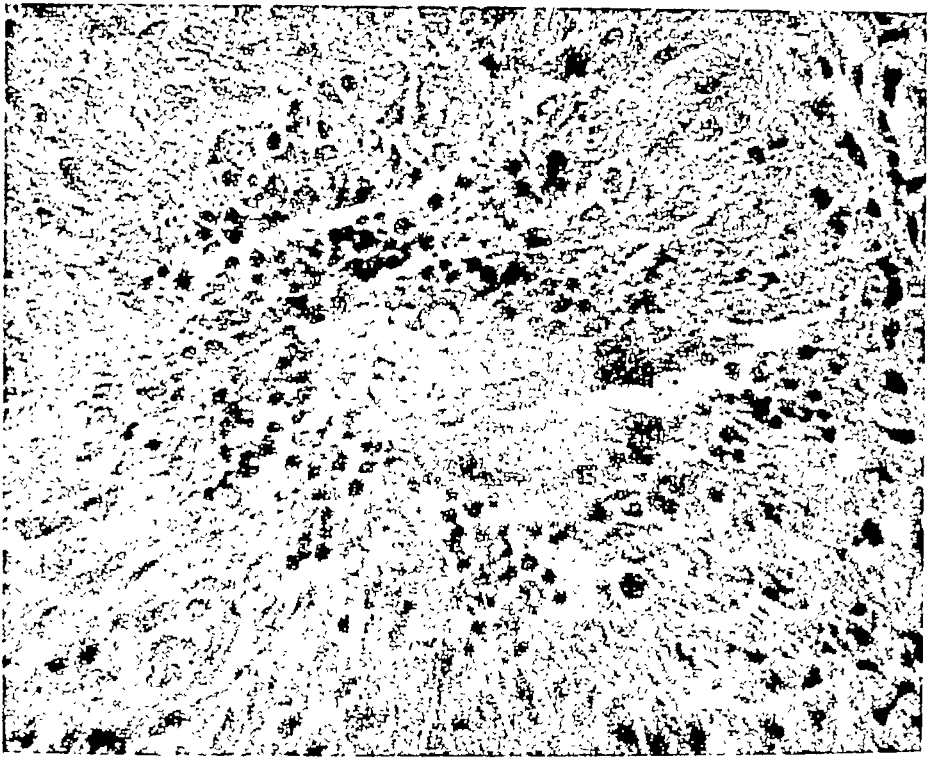

Fig. 3 (Case 1).—Photomicrograph illustrating a round spherule filled with endospores found in cyst wall.

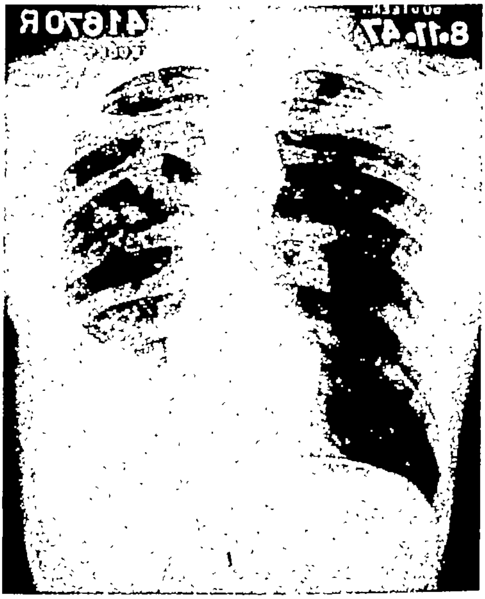

Fig. 4 (Case 1).—X-ray film taken Aug. 8, 1947, at Veterans Administration Hospital, Oteen, N. C., three months after right lower lobectomy. Note degree of expansion of middle lobe.

Coccidioides culture, the condition was diagnosed as coccidioidomycosis with cavitation. Apparently we were dealing with a residual cavity from a prior attack of primary coccidioidomycosis which was asymptomatic.

May 8, 1947, under cyclopropane and ethylene anesthesia a right lower lobectomy was performed. The patient was given 1,000 c.c. of whole blood and 1,300 c.c. of a 5 per cent solution of glucose in saline during the operation. A 2.5 cm. thin-walled cavity was found in the right upper lobe. On microscopic examination the wall of this cavity was seen to consist of a caseous mass supported by granulation tissue made up of capillaries, plasma cells, eosinophiles, and polymorphonuclear leucocytes. In the granulation zone was a slightly distorted, pale-blue staining spherule filled with endospores (Fig. 3). Giant cells in a few instances contained one or several spherules. In the adjoining lung tissue numerous structures resembling epitheloid cell tubercles were seen. The microscopic diagnosis was coccidioidomycosis of the lower lobe of the right lung, granulomatous and cavity-forming.

The postoperative course was uneventful except for a hydrothorax which was aspirated once on May 15, 1947. Seven hundred cubic centimeters of serosanguineous fluid were removed and were found negative for *Coccidioides immitis*. The sputum remained positive on smear, concentrate, and culture for spherules. In an effort to find the source of the positive sputum, planigrams of both lung fields were made but these revealed no further evidence of cavitation. Bronchoscopy on July 8, 1947, showed reddening of the right middle orifice but no signs of endobronchial disease. Bronchoscopy on July 29, 1947, was negative.

Potassium iodide and sulfadiazine were given for one week followed by a therapeutic intratracheal instillation of iodized oil on Aug. 21, 1947. The sputum turned negative on concentrate but remained positive on culture for spherules of *Coccidioides immitis*.

X-ray examination Aug. 8, 1947, showed re-expansion of the upper and middle lobes of the right lung (see Fig. 4). The patient was asymptomatic and was gaining weight. He was discharged Aug. 30, 1947, three months and twenty-three days after lobectomy.

He returned to the hospital for a check-up examination Dec. 15, 1947. At this time he was asymptomatic and working regularly. The sputum examinations (smear and culture) March 3, 1948, were negative for *Coccidioides immitis*.

Comment.—This case illustrates the innocent roentgenographic appearance and innocuous behavior of cavitation following primary quiescent coccidioidomycosis. Undoubtedly this patient had a primary infection during military service which was asymptomatic. At separation center his residual cavity was discovered. The condition was diagnosed as pulmonary tuberculosis, a common error in these cases. When no acid-fast bacilli could be found on repeated and extensive study, the condition was then diagnosed as cyst of the lung. A positive sputum for *Coccidioides immitis* was not obtained until fifteen months after the cavity was discovered. The difficulty of making the correct diagnosis is clearly demonstrated by this case.

The symptom of posterior chest pain over the cavity is a common finding in residual pulmonary cavities. The usual symptoms of fever and loss of weight were not present. An important observation is the increase in the size of the cavity (Figs. 1 and 2) during the four and one-half months of bed rest. The cavity remained large, as Fig. 2 indicates, until lobectomy eleven months later.

At first a phreniclasia was done in an attempt to close the cavity, but this was unsuccessful. When cavities are large, phreniclasia is usually of no value. In view of the persistence of the cavity and the danger of dissemination or hemoptysis, a lobectomy was considered the treatment of choice in this case. Following lobectomy the sputum remained positive, although planigrams of both lung fields and bronchoscopy revealed no further evidence of disease. A positive sputum does not constitute a public health menace, for coccidioidomycosis is produced by the chlamydospores of the fungus which are contacted from the environment in endemic areas. Infection does not pass from person to person via sputum containing endospores or spherules.[6] Unlike tuberculosis, the spherule does not lend itself to dissemination of the fungus outside the animal body.

At the time of discharge this patient was asymptomatic and gaining weight. He returned to his occupation as waiter. On follow-up examination six months after discharge he was still symptom free and sputum was negative. In this case we feel that lobectomy provided the most effective method of treatment.

CASE 2.—B. S., a 25-year-old white man, served in the army from Jan. 16, 1944, until March 26, 1946. Part of the time he was stationed in Texas, Arizona, California, and the European theater. While in the army he had no symptoms of coccidioidomycosis or any related disease.

During the summer of 1946 (three months after discharge) he first noticed that he felt unusually weak, tired easily, and was losing weight. He developed a cough which was productive of a moderate amount of grayish-brown sputum and complained of soreness and pain beneath his sternum. He paid little attention to these symptoms, however, and continued working as a mechanic in a garage. Symptoms persisted, and in November, 1946, he first observed blood-streaked sputum. There was never any hemorrhage but he coughed up as much as a tablespoonful of blood at a time. This condition did not improve. In December, 1946, he went to his local physician for the first time. Upon roentgenologic examination a large cavity was discovered in the upper lobe of the left lung with no involvement of the right lung (see Fig. 5).

On Jan. 8, 1947, he was admitted to the Veterans Administration Hospital, Swannanoa, N. C. Chief symptoms were cough, blood-streaked sputum, and a weight loss of thirty pounds even though the appetite remained good. At this time he complained of pains "between the shoulder blades and severe left chest aching" at night. Physical examination revealed a well-developed, well-nourished white man who did not appear acutely or chronically ill. Examination of the lungs showed coarse breath sounds over the left apex posteriorly. No râles were present. Temperature was 99° F.; the blood pressure was 140 systolic, 80 diastolic, and pulse 80 per minute. The remainder of the physical examination was essentially negative.

Laboratory Findings.—On admission the total erythrocyte count was 4,930,000, hemoglobin 94 per cent, and the total leucocyte count 7,950 with 61 per cent polymorphonuclears, 34 per cent lymphocytes, with 4 per cent monocytes and 1 per cent basophiles. The erythrocyte sedimentation rate (Wintrobe, corrected) was 6 mm. per hour. Urinalysis revealed amber color, acid reaction, a specific gravity of 1.024, negative for sugar and albumin, and a few white blood cells on microscopic examination. Serology (Kahn and Kolmer) was negative. The total serum protein was 7.1 Gm. per cent with albumin 4.6 and globulin 2.5 Gm. per cent. The coccidioidin skin test was positive (30 mm.) 1:1,000 dilution. Tuberculin skin test (0.05 mg., purified protein derivative) was positive (10 mm.). Histoplasmin skin test was negative in 1:1,000 and 1:10 dilutions. All sputum smears, concentrates, and guinea pig inoculations were negative for acid-fast bacilli. Bronchoscopy on Feb. 17, 1947, revealed a minimal amount of blood seen at the left main-stem bronchus. Smear and culture were negative for acid-fast bacilli but a positive culture of *Coccidioides immitis* was found.

Planigrams on Feb. 28, 1947, revealed a mottled infiltration and a thin-walled cavity in the upper lobe of the left lung. March 7, 1947, a left bronchogram was done and iodized oil filled the cavity (see Fig. 6).

A diagnosis of pulmonary coccidioidomycosis with cavitation in the left upper lobe was made and the patient transferred to the Veterans Administration Hospital, Oteen, N. C.,

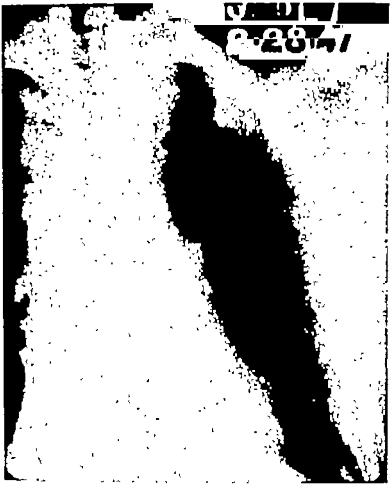

Fig. 5.

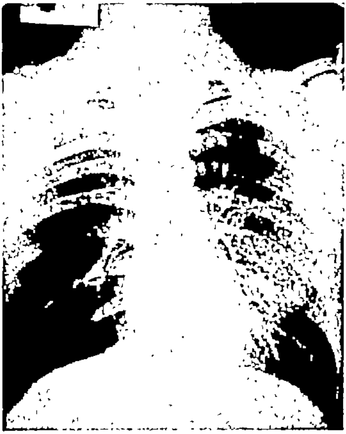

Fig. 6.

Fig. 5 (Case 2).—Planigram taken Feb. 28, 1947, at Swannanoa Division of Veterans Administration Hospital, Oteen, N. C., showing solitary thin-walled cyst (under fourth rib) in left upper lobe.

Fig. 6 (Case 2).—Bronchogram taken March 7, 1947, at Swannanoa Division of Veterans Administration Hospital, Oteen, N. C., demonstrating size of the cavity (between fourth and fifth ribs) by Lipiodol.

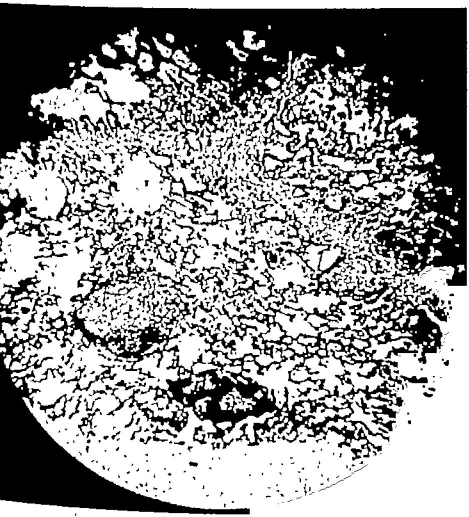

Fig. 7.

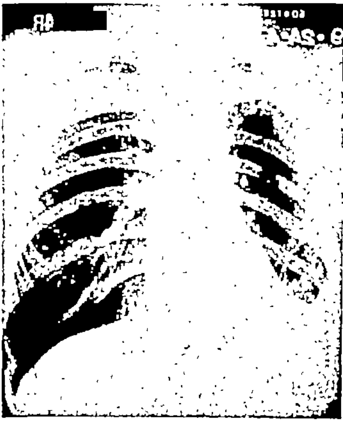

Fig. 8.

Fig. 7 (Case 2).—Photomicrograph illustrating spherules of *Coccidioides immitis* within giant cells. Note chronic granulation tissue.

Fig. 8 (Case 2).—X-ray film taken Sept. 24, 1947, at Veterans Administration Hospital, Oteen, N. C., showing expanded lower lobe three months, eighteen days following left upper lobectomy.

on April 1, 1947. He still complained of pain in the left chest and cough which was productive of blood-streaked sputum. Blood count, urinalysis, and serology were negative. The vital capacity was 5,200 c.c. (normal: 5,050 c.c.). Sputum smears, concentrates, and cultures for acid-fast bacilli were negative. Spherules of *Coccidioides immitis* were found in the sputum on April 2 and April 4, and cultures were positive for *Coccidioides immitis.* The erythrocyte sedimentation rate was 2 mm. per hour (Wintrobe, corrected).

Planigrams on April 10, 1947, again demonstrated the cavity in the left infraclavicular region. The right lung remained clear. The electrocardiographic tracing was normal.

A diagnosis of coccidioidomycosis with cavitation in the left upper lobe was made and the therapy conference board recommended left upper lobectomy, which was performed May 6, 1947, under cyclopropane and ethylene anesthesia. During the operation he received 1,000 c.c. of whole blood, 1,000 c.c. of plasma, and 1,000 c.c. of a 5 per cent solution of glucose in normal saline solution.

The pathologist reported a 2.2 by 1.1 cm. cavity in the left upper lobe. On microscopic section the lesions everywhere resembled those found in tuberculosis, except for fine histologic detail. Spherules of *Coccidioides immitis* were found within giant cells or free in tubercles (see Fig. 7). Surrounding the tubercles and elsewhere was chronic nonspecific granulation tissue and fibrosis. Part of the peribronchial lymph nodes showed preserved follicular structure, but in other sections there were epitheloid cell tubercles and giant cells undergoing caseation. The final diagnosis was coccidioidomycosis of the upper lobe of the left lung, granulomatous and cavity-forming, involving peribronchial lymph node.

The entire postoperative course was uneventful and the remainder of the lung gradually re-expanded. This patient was discharged asymptomatic May 29, 1947 (twenty-three days following lobectomy). A follow-up x-ray film on Sept. 24, 1947, three months, eighteen days after operation, showed the remainder of the left lobe fully expanded (Fig. 8). This patient had no complaints and was working every day with no ill effect.

Comment.—This case also illustrates the asymptomatic character of primary coccidioidomycosis with pulmonary cavitation as a residual complication. This patient served in endemic coccidioidal areas but was never ill. Three months after discharge he noticed the first symptoms: weakness, loss of weight, and cough productive of grayish-white sputum—symptoms similar to those of tuberculosis with which coccidioidomycosis is often confused. Later hemoptysis (but not hemorrhage) and chest pain were noted, symptoms characteristic of residual coccidioidal cavities.

The erythrocyte sedimentation rate and other laboratory data were essentially negative. Both the tuberculin and the coccidioidal skin tests were positive, a common finding in coccidioidal infection. *Coccidioides immitis* was found in the sputum nine months after symptoms were first noted.

Judging from our previous experience with phreniclasia, it was felt that this procedure would not close the cavity, especially since it was located in the left upper lobe. In view of the large size of the cavity, lobectomy was considered the treatment of choice. The sputum was negative following surgery and the patient was discharged twenty-three days after operation. When seen nine months after discharge, he was still asymptomatic and working daily at his former occupation. In this instance lobectomy achieved a gratifying end result.

DISCUSSION

In the past it has been the general consensus of opinion that pulmonary cavitation following coccidioidomycosis should be treated conservatively. In

1942 Winn[4] reported twelve cases of pulmonary cavitation treated from four months to four years under normal and unrestricted living and working conditions without collapse therapy. In five, the cavities closed spontaneously; in the remaining seven, the cavities remained with little change in roentgenographic appearance and without evidence of dissemination. In two cases Winn employed pneumothorax successfully for excessive bleeding. Two other patients had open cavities six months and two and one-half years after pneumothorax treatment. Both cavities closed after the lung was re-expanded. Winn concluded that persistent pulmonary hemorrhage or the occasional large cavity associated with the continuous production of spherule-laden sputum may be an indication for simple collapse measures.

Denenholz,[5] in 1944, reported a series of five patients with pulmonary cavities which were treated by bed rest and the application of a cloth bag containing lead shot over the anterior aspect of the portion of the chest involved. The weight applied began at three pounds (1.5 kg.) and gradually was increased to eight pounds (3.6 kg.). He believed that cavities closed more rapidly on this method of treatment than with bed rest alone. He did not employ pneumothorax in any of his cases. Phreniclasia was used in two cases to reduce the size of the cavity. Denenholz also mentioned immobilization with a lead shot bag as of some benefit in helping to close thin-walled cavities.

Thus, there are many opinions as to the method of treatment of pulmonary cavitation in coccidioidomycosis. In some instances the patients have continued to work and the cavities have closed without any treatment. Rest in bed has been successful in other instances. Phreniclasia and immobilization with lead shot bag have been used as an adjunct to bed rest. Lobectomy has been employed in two previous cases and here at Oteen in two cases. We should like to emphasize the importance of lobectomy for patients with residual thin-walled cavities.

Two main dangers must be faced in any patient with a residual pulmonary cavity from coccidioidomycosis. The first is the possibility of dissemination of the pulmonary disease to other parts of the body. Denenholz[5] stated that the mortality is greater than 50 per cent in disseminated coccidioidomycosis, although dissemination rarely occurs. Quill and Burch[7] reported four cases of disseminated coccidioidomycosis in 1944. Two of the patients died in two months and the other two in four months, a mortality of 100 per cent. Dissemination is definitely a serious and usually fatal sequela in any patient with a pulmonary cavity.

The second danger is hemoptysis. It is generally agreed that patients who have had one or more pulmonary hemorrhages from their cavity should have immediate and adequate therapy to stop the hemoptysis. Pneumothorax has been tried in some cases as reported by Peers, Holman and Smith[1] but without success. Phreniclasia has been tried, as in our first case, without success. Hemoptysis is a distressing symptom and if unchecked is usually fatal.

Lobectomy definitely appears the most practical and efficient method of treatment for a patient with a residual cavity from primary coccidioidomycosis.

Excision of the diseased lobe averts all risk of dissemination and hemoptysis. The patient is then free of his disease and will not live in constant fear of the development of a fatal complication. Also, he will be relieved of the symptom of pain in the chest, a common symptom and one exhibited by both of our patients.

We realize that lobectomy is a new and different form of therapy for residual coccidioidal cavitation but believe that the nature and complications of the disease warrant immediate and extensive treatment. The results in our two patients, as reported above, seem to justify the employment of this procedure. Time and the end results in similar cases may afford the answer to the problem.

SUMMARY

1. The literature on the treatment of pulmonary cavitation in coccidioidomycosis has been briefly reviewed.
2. Two cases of residual pulmonary cavitation following primary coccidioidomycosis are reported, both successfully treated by lobectomy.
3. Lobectomy is recommended as an effective and practical method of treatment in similar cases.

ADDENDUM

CASE 2.—B. S. was readmitted Aug. 30, 1948, complaining of severe nonproductive cough, weakness, and night sweats. X-ray examination showed a thin-walled cavity 4 cm. in diameter in the upper portion of the remaining left lower lobe. Surrounding the cavity were productive strands and small areas of exudative disease. The sputum was positive for acid-fast bacilli. Coccidioidin skin test was negative in the 1:1000 and 1:100 dilution on Sept. 7, 1948. On Jan. 10, 1949, it was reported positive in dilution of 1:1000. Culture of the sputum was negative for coccidioides.

A seven-rib left thoracoplasty was completed Nov. 17, 1948. The surgical collapse had little effect on the cavity, which remained thin-walled and with a diameter of 3 cm. An open cavernostomy was completed on March 3, 1949. Smears from the cavity wall showed coccidioidal spherules, as did tissue sections. Culture of the material from the cavity was positive for tubercle bacilli.

The patient remains in the hospital. The cavernostomy has not completely obliterated the cavity. The course following the original lobectomy has not confirmed our early optimism.

REFERENCES

1. Peers, R. A., Holman, E. F., and Smith, C. E.: Pulmonary Coccidioidal Disease, Am. Rev. Tuberc. 45: 723-740, 1942.
2. Blades, Brian: Personal communication.
3. Winn, W. A.: Pulmonary Cavitation Associated With Coccidioidal Infection, Arch. Int. Med. 68: 1179-1214, 1941.
4. Winn, W. A.: The Treatment of Pulmonary Cavitation Due to Coccidiodal Infection, California & West. Med. 57: 45-47, 1942.
5. Denenholz, E. J.: Diagnosis and Treatment of Chronic Coccidioidomycosis, Arch. Int. Med. 74: 311-330, 1944.
6. Smith, C. E.: Coccidioidomycosis, M. Clin. North America 27: 790-807, 1943.
7. Quill, L. M., and Burch, J. C.: Surgical Manifestations of Coccidioidomycosis, Ann. Surg. 120: 670-679, 1944.

CARCINOMA OF THE ESOPHAGUS

USE OF RIGID INDWELLING ESOPHAGEAL TUBE

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A HIGH percentage of esophageal malignancies proves to be inoperable upon exploration. The surgeon is then confronted with the onerous choice of allowing the patient to starve or of performing a gastrostomy or similar procedure.

This alternative presented itself a year ago during an exploratory laparotomy, in a case of epidermoid carcinoma of the esophagus with involvement of the aorta by direct extension. It was decided to attempt to establish a permanent artificial lumen through the malignant constriction by means of a rigid nonabsorbable tube. A silver tube was fashioned and inserted through a longitudinal slit in the lower end of the esophagus into its lumen. This tube, 9.4 cm. in length and 8 mm. in diameter, was then passed up through the constricting malignancy under direct vision. The passage of the tube was further facilitated by threading it upwards over a Levine tube. This prevented inadvertent perforation of the esophageal wall. The tube ends extended more than 3 cm. above and below the constriction. The tube had been slightly flanged

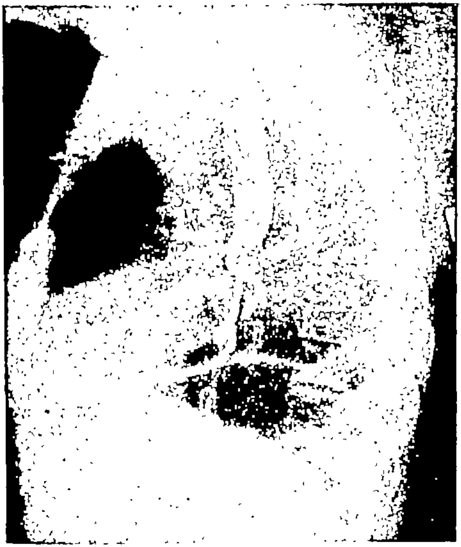
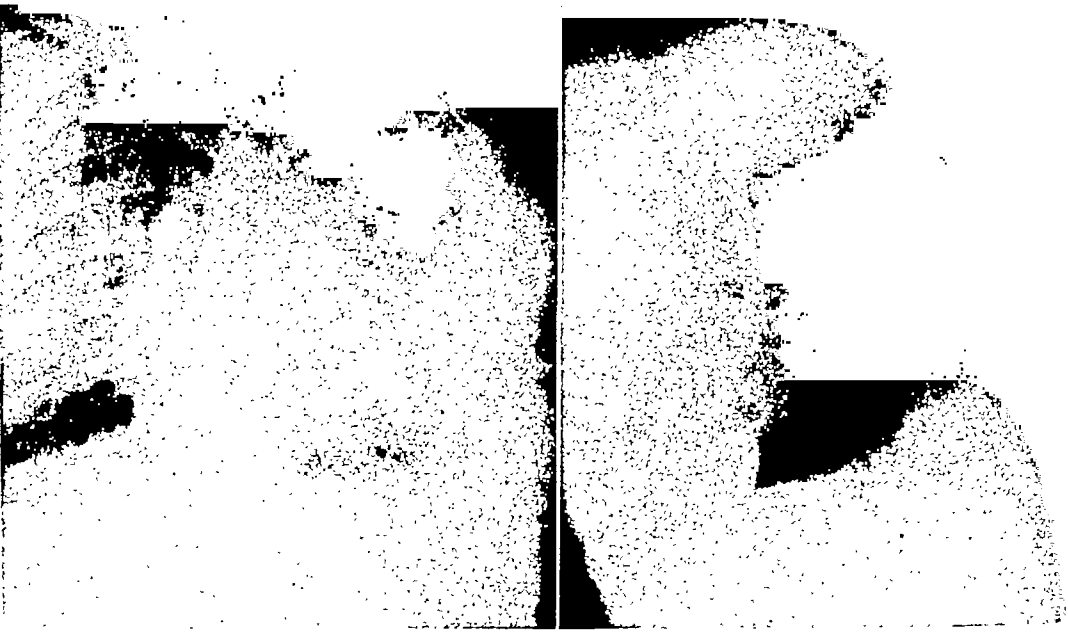


Fig. 1.—Lateral view of the esophagus showing irregularity of wall and site of constriction by tumor.

From the Department of Thoracic Surgery, Mount Zion Hospital.
Received for publication April 22, 1948.



A. B.

Fig. 2.—Anteroposterior and lateral views taken immediately after surgery showing position of metallic tube in midesophagus.

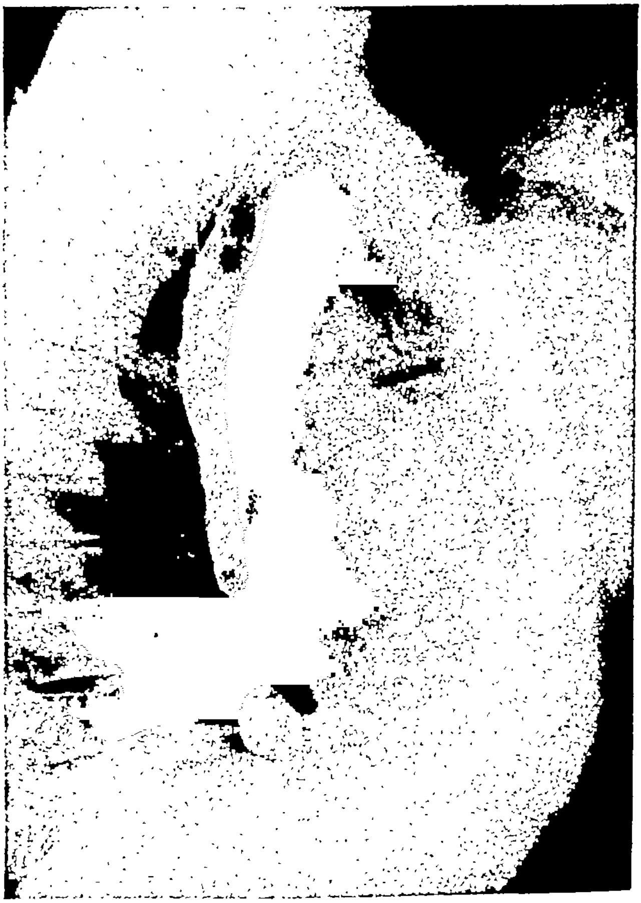


Fig. 3.—Appearance of esophagus six months after radiation and spontaneous passage of metal tube. The constriction noted above the diaphragm is, we feel, due to the cellophane ligature.

at its distal end. The attempt was then made to keep it in position by fixing the distal esophageal end in an "S" shaped manner to the posterior chest wall and by placing a flat ligature of cellophane around the esophagus just distal to the end of the tube, *slightly constricting the esophagus at this point.* These procedures formed a shelf which kept the tube from falling down toward the stomach and the flange kept it from passing upward into the buccal cavity.

It has been possible to feed the patient by mouth since operation. The diet is, of course, similar in consistency to that used through a gastrostomy tube but I do not believe that the manifold advantages of mouth feeding versus gastrostomy feeding need be stressed here.

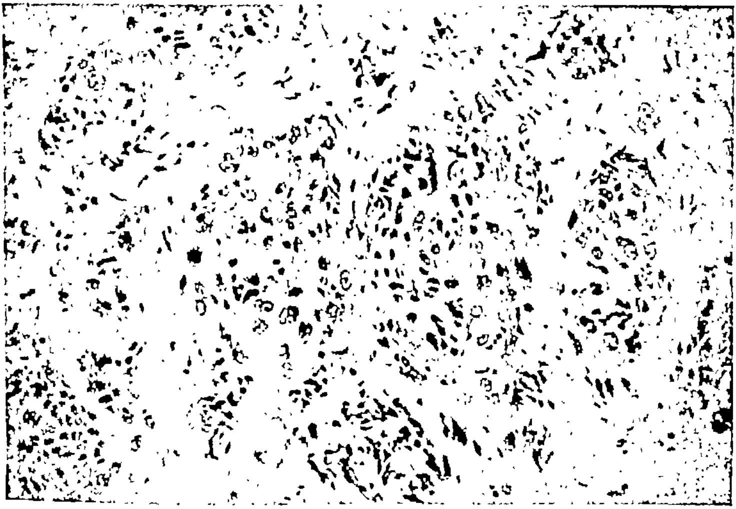


Fig. 4.—Microphotograph of the tumor tissue obtained preoperatively by biopsy done at esophagoscopy.

The patient was immediately treated by roentgen radiation according to the multiple-port method of Demy,* receiving a total of 20,000 r. over a period of thirty-one days, which gave an actual 5,000 r. to the tumor area. This caused a quick recession of the mass so that there was sufficient shrinkage to allow the spontaneous passage of the tube in thirty days. Esophagoscopy, six months after radiation, revealed a widely patent lumen throughout and no visible evidence of malignancy.

It is believed that whether or not a patient receives such benefit from radiation, the use of a rigid indwelling esophageal tube, as described above, may be worth while.

The exact material from which the tube should be fashioned to be most applicable for this purpose is at present under investigation.

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*Demy, Nicholas G.: Beam Localization and Depth Dose Determination, Radiology 51: 89-99, 1948.

DECOLLATION OF INTRAPLEURAL ADHESIONS BY OPEN EXTRAPLEURAL PNEUMONOLYSIS

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ARTIFICIAL pneumothorax in the treatment of pulmonary tuberculosis is usually complicated by the presence of intrapleural adhesions. In many cases the lung can be effectively freed by thoracoscopy and internal pneumonolysis. Where adhesiotomy by this method cannot be achieved to a degree which allows adequate relaxation and cavity closure, modern authorities[5] advise that the pneumothorax be abandoned and alternative treatment, usually thoracoplasty, essayed.

While the physician may see little difference in magnitude between artificial pneumothorax and thoracoplasty, some, indeed, preferring the latter method without preliminary trial of the former, *(thoracoplastie d' emblée[6])* the patient is likely to hold different views. He sees a small operative mortality, not in broad actuarial terms, but with himself as possibly in the unlucky 5 per cent. Postthoracoplasty deformity, minimized though this may be by improved methods, is still a disagreeable prospect, especially to a young woman. This operation, in fact, is regarded by most patients as a last resort, to be accepted if there is no possible alternative.

We ought, therefore, before abandoning a pneumothorax because of indivisible adhesions, to consider carefully any other means by which it might be rendered effective. One method which has found limited favor is the so-called "fenestration" extrapleural pneumothorax.[7] This is performed in addition to the existing intrapleural pneumothorax, the two air spaces then being joined by cutting through the double pleural layer that divides them at that stage, the combined space being refilled thereafter as an ordinary intrapleural pneumothorax. This operation is not exacting to the patient and a hazard of earlier days, the introduction of secondary infection, is now mitigated by chemotherapy. However, an initially good result is very likely to become disappointing later. A good deal of blood inevitably oozes from the large raw area over the thoracic dome and even by early and frequent aspiration it is very difficult to keep the space dry. Whether for this reason, or because a broad flap of combined pleura is left hanging more or less free over the upper part of the relaxed lung, fresh adhesion tends to take place and is followed by firm organization between lung and chest wall. This occurrence, even if it does not immediately interfere with the collapse, is very often succeeded by loss of the space altogether by adhesive pleuritis.

By adopting a modification of this operation, we believe we have avoided these objections.

From the Tuberculosis Service, Otago Hospital Board, New Zealand.
Read at the Annual Meeting of the British Medical Association, New Zealand Branch, Feb. 4, 1948.
Received for publication May 11, 1948.

CASE REPORTS

CASE 1.—A salesman, aged 31 years, was found to have pulmonary tuberculosis in June, 1946, on routine examination after the death of his infant son from tuberculous meningitis. *He had a cavitary lesion of moderate extent in the left upper lobe, with* tubercle bacilli in the sputum. Left artificial pneumothorax was induced on August 8, and at successive thoracoscopies on October 11 and December 12 several fine apicoposterior adhesions were divided by galvanocautery. One short, broad, apicolateral adhesion was judged too dangerous to attempt, so that the lung was left firmly anchored to the chest wall at this point. The cavity remained patent, despite a crush of the left phrenic nerve to assist relaxation, and the sputum continued to contain tubercle bacilli (Fig. 1). At this juncture the patient was told that the pneumothorax must be abandoned and that he should prepare himself for thoracoplasty, a prospect for which he displayed no enthusiasm. We decided, therefore, to compromise by attempting first a fenestration extrapleural operation, with the proviso that thoracoplasty might still ultimately be required. On Feb. 11, 1947, under basal narcosis and nitrous oxide inhalation, the chest was opened by removing a 4-inch section of the left fourth rib posteriorly. The periosteum was divided and parietal pleura was readily stripped from the endothoracic fascia by finger dissection over the apex of the lung. The circular base of the intrapleural adhesion, about 1½ inches in diameter, was now easily distinguished by palpation from the free pleural surface surrounding it. We knew from previous thoracoscopic examination that no other adhesion was present and we, therefore, decided to carry the stripping operation no further. A nick was made through the parietal pleura close to the base of the adhesion and was carried

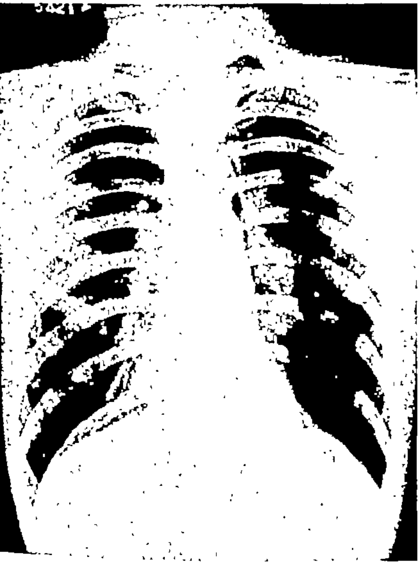


Fig. 1.

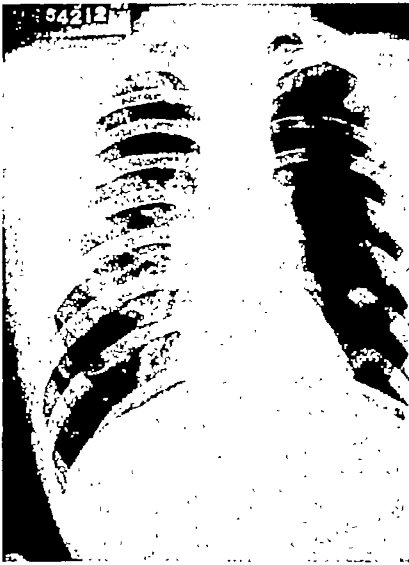
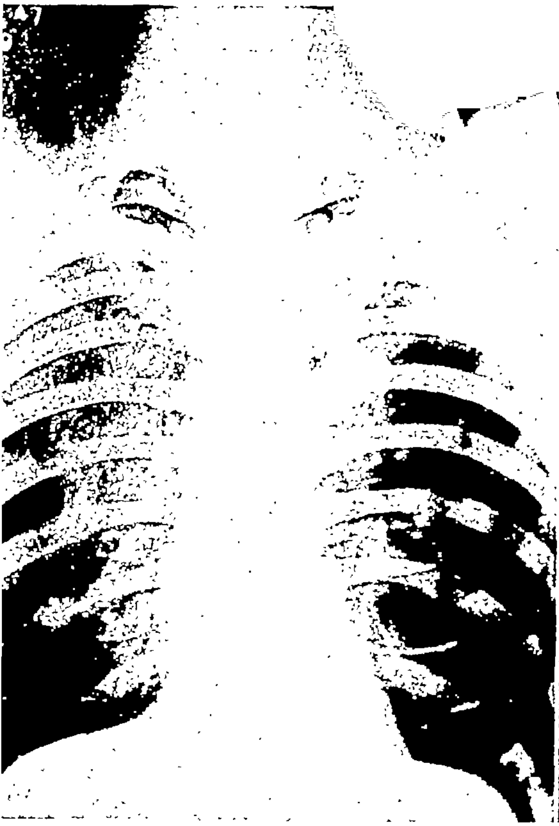


Fig. 2.

Fig. 1 (Case 1).—With left artificial pneumothorax, after thoracoscopic division of adhesions and phrenic nerve crush. Lung still adherent, cavity patent.

Fig. 2 (Case 1).—After extrapleural decollation of the remaining adhesion. Lung completely free, cavity closed.

around with scissors to a complete circle. The excised adhesion dropped back into the pleural cavity. The cut edges of the parietal pleura were sutured together and the wound closed in layers. Moderate subcutaneous emphysema developed during the next twelve hours but the patient had very little constitutional upset. An air refill of 500 c.c. was given on the second day and on the third day 600 c.c. of dark fluid blood were aspirated from the pleural cavity. Only 40 c.c. more were removed a day later, the usual difficulty being experienced in drying out the space. The remaining bloody exudate, however, became absorbed without any obvious adhesion taking place. The intrapulmonary cavity closed immediately, the sputum became negative for tuberculosis and soon disappeared (Fig. 2). The patient is today well and working, the pneumothorax being maintained by biweekly refills, with pressures on the negative side of zero.



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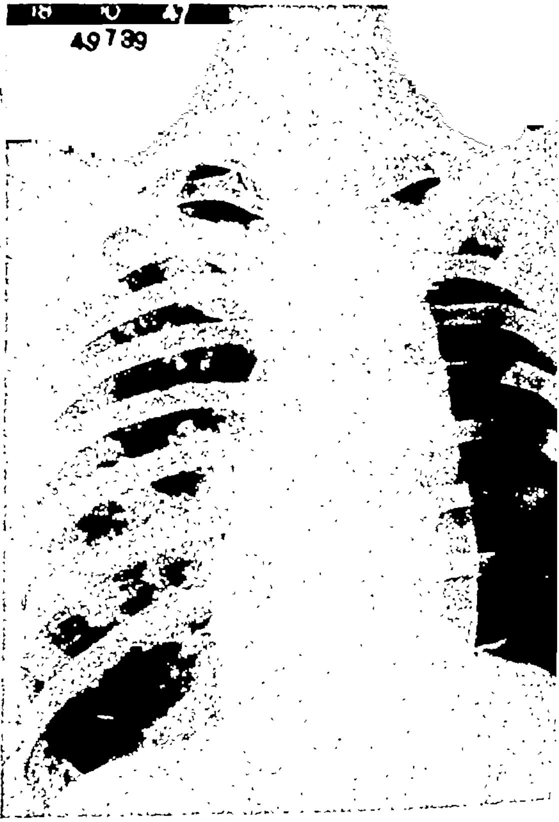


Fig. 4.

Fig. 3 (Case 2).—With left artificial pneumothorax. Lung adherent over a broad area, cavities still patent.

Fig. 4 (Case 2).—After decollation of the adhesion-complex. Lung collapsed against the mediastinum, cavities closed.

Case 2.—This patient was a factory foreman, aged 44 years, with a tuberculous lesion detected in 1945. In June, 1947, definite activity was established, the lesion occupying the left lung apex with a cavity beneath the clavicle 1 inch in diameter. Artificial pneumothorax was induced on July 18. The roentgenologic appearances (Fig. 3) suggested that the lung was massively adherent over the apex and thoracoscopy was not attempted. On October 1 the chest was opened under local anesthesia, a 4-inch piece of the fourth rib being removed posteriorly, as in Case 1. The parietal pleura was stripped from the endothoracic fascia by blunt dissection until the whole vault was free. A fenestration was then made into the pleural cavity. Direct inspection revealed a number of stringlike adhesions which were easily divided by galvanocautery, leaving a broad apical symphysis. The pleural opening was carried right around this island of adhesion, which then dropped back. The pleural edges were sutured and the wound closed. Apart from subcutaneous emphysema the patient experienced no postoperative effects and was transferred back to the sanatorium on the fifth day because he felt too well to be in a hospital ward. The lung was so far collapsed that no refill was necessary until October 28. Some effusion formed during this period but as it did not increase, no aspiration was performed until December 4, when 600 c.c. of clear, pale yellow fluid were removed. The pleural space has since remained dry and the lung cavity, which still appeared patent six weeks after operation, is now apparently closed (Fig. 4). The sputum is negative for tuberculosis and he has left the sanatorium, on biweekly refills of between 250 and 400 c.c.

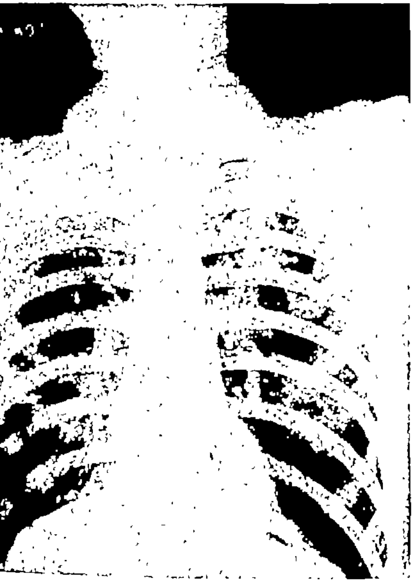


Fig. 5.

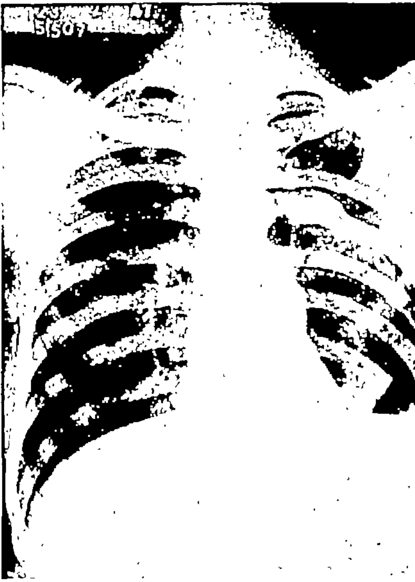
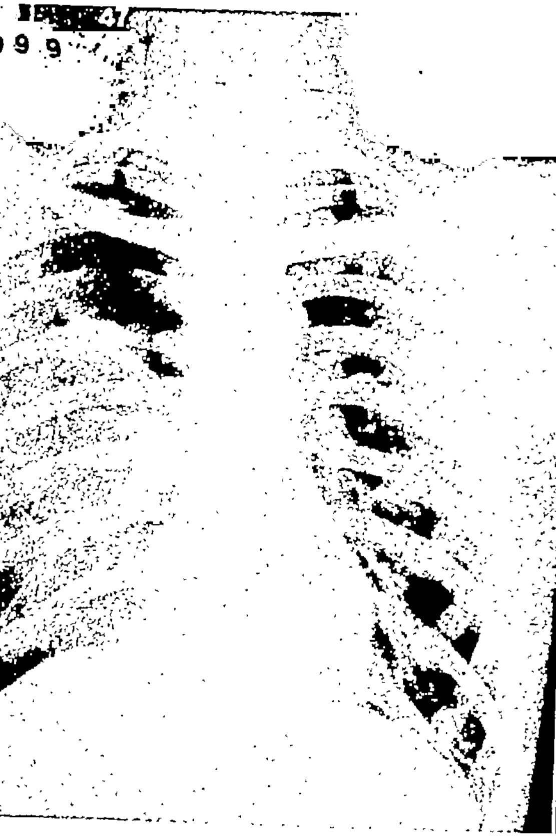


Fig. 6.

Fig. 5 (Case 3).—With left artificial pneumothorax. Lung widely adherent over the apex, cavity still patent.

Fig. 6 (Case 3).—After decollation of the adhesion. Lung completely free, cavity closed.

Case 3.—A surgical-appliance technician, in a routine x-ray examination taken on discharge from the army in 1945, was found to have bilateral pulmonary tuberculosis. After six months of routine sanatorium treatment he was well enough to resume his civilian job, but signs of reactivation appeared in October, 1947, with a rise of the sedimentation rate to 20 mm. and the appearance of tubercle bacilli in the sputum. There was at this time infiltration in both lung apices with probable cavitation on the left. An artificial pneumothorax was induced on this side on October 22, but a massive adhesion was found to anchor the lung posterolaterally near the apex (Fig. 5). On December 2, under local anesthesia, a 3-inch piece of the fourth rib was removed posteriorly and the parietal pleura stripped as in previous cases over the thoracic vault. Opening up the pleural space showed a short symphysitic adhesion-complex which was enucleated by a circular section. The released lung fell back. The wound was closed in layers, the breach in the parietal pleura being left unsutured. The postoperative course was uneventful, without even substantial subcutaneous emphysema. The patient returned to the sanatorium on the fourth day and had his first refill four days later. There was no significant intrapleural effusion. The pulmonary collapse is entirely satisfactory (Fig. 6) and though there is still a trace of sputum this is negative for tuberculosis on culture.



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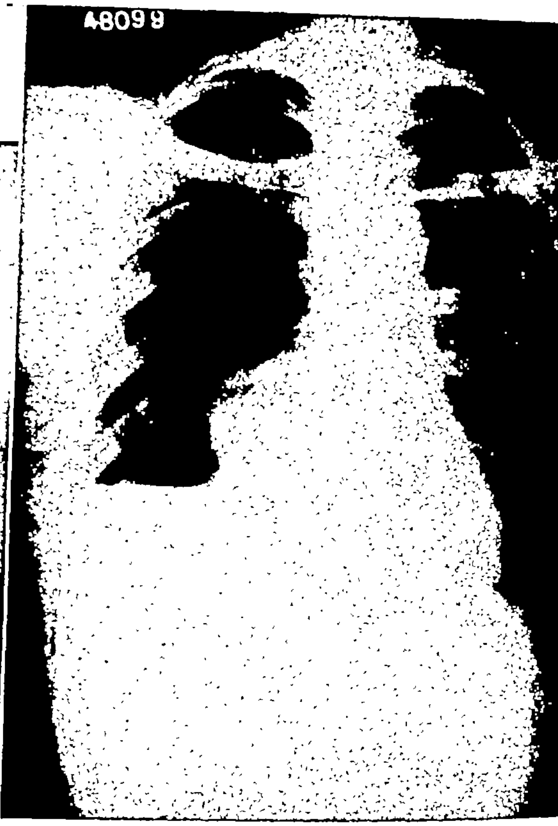

Fig. 8.

Fig. 7 (Case 4).—With right artificial pneumothorax, after thoracoscopic division of adhesions. Lung still anchored posterolaterally, cavity still patent.

Fig. 8 (Case 4).—After decollation of the remaining adhesion. Lung massively collapsed, cavity closed.

Case 4.—A post-office clerk, aged 27 years was found to have pulmonary tuberculosis while on active service abroad in 1944. After rest treatment in various institutions, he returned to his job in the post office and kept well up to October, 1946, when he was admitted to hospital with hemoptysis. He came under our care in October, 1947, with extensive bilateral disease and tubercle bacilli in the sputum. A right artificial pneumothorax was induced on October 10, and on November 11, thoracoscopy was performed. Three apical strings were divided but a short, thick spool-shaped band running posterolaterally from the subapical part of the lung was judged too dangerous to interfere with intrapleurally. Fig. 7 shows the position after thoracoscopy. On December 1, a 3-inch section of the fourth rib was resected under local anesthesia. After separation of the parietal pleura, the base of the adhesion was found to lie directly beneath the exposed surface. Very little stripping was required to define its circular border, 1 inch in diameter, and an incision around this island base freed the lung completely. The wound was closed without suturing the parietal pleura. Next day the patient was rather dyspneic and was found to have a massive collapse of the right lung with displacement of the heart and mediastinum to the left (Fig. 8). No considerable effusion developed, however, and the lung gradually became aerated. The pneumothorax is now controlled by weekly refills of 500 c.c., the sputum is negative for tuberculosis and apparently the cavities are closed.

COMMENT

We have preferred an incision along the line of the fourth rib to the vertical paravertebral incision used by many surgeons for the operation of extrapleural pneumothorax.[1] This seems to give no greater tendency to subsequent limitation of movement if physiotherapeutic measures are instituted early. Active exercises are begun the day following operation. Penicillin, 15,000 units every three hours, is given parenterally as a routine for forty-eight hours after operation and then discontinued if the temperature is normal.

Preliminary thoracoscopy is an advantage, even if it seems likely that no adhesiotomy will be possible at that stage. In Cases 2 and 3 this was omitted, perhaps with no great loss. In Case 4, however, in addition to enabling us to free some adhesions, thoracoscopy showed us that the adhesion to be decollated extrapleurally was based right on the fourth rib, so that the usual posterior approach would lie directly over it. Thus, a very small area of stripping was required, with consequent absence of hemorrhage. We propose in the future always to approach the objective as closely as possible, unless, of course, more than one adhesion is involved.

DISCUSSION

We feel confident, even from a small experience, that we have evolved a method of liberating adhesions of a type that cannot be dealt with by internal pneumonolysis, because they are too short, or too massive, or too close to vulnerable structures, or too vascular, or because they contain lung tissue or tuberculous foci. If our technique has been used by others, we have found no published description, except of the extrapleural fenestration operation, of which it may be regarded as a development.

Adhesions in this class may sometimes be freed by *décollement* of their parietal attachments, either by means of the thoracoscope and cautery[3, 4] or by open thoracotomy[2] from within the pleural cavity. We are not persuaded that success can easily be achieved in this way except in the case of relatively small and mobile adhesions, where it is possible to define the limits of the basal island on every side. Even so, the subparietal area beneath remains an unknown factor. Local anesthesia from the intrapleural approach is difficult and the enucleation of the head of the adhesion is tedious and risky, even in experienced hands. Our technique, on the contrary, is exceedingly simple, free from risk of uncontrollable hemorrhage, and not much more exacting to the patient than a routine thoracoscopy. The area of operation is anesthetized, the adhesion base can be examined both intrapleurally and extrapleurally before detachment, there are no large vessels liable to damage. Tuberculous tissue is not likely to be opened unless the adhesive area is very dense, in which case no further pleural separation is attempted.

Our four cases make a modest total from which to draw conclusions. This is due to two factors. First, in the majority of patients with artificial pneumothorax where the treatment looks hopeful from the start, the lung can be effectively freed by thoracoscopic methods. Second, artificial pneumothorax has in our practice been replaced in certain types of cases as it has come to be preceded in a great number of cases, by artificial pneumoperitoneum combined with, or without, phrenic nerve interruption. For this reason we have not yet found more instances in which extrapleural decollation appears indicated. We are encouraged to believe that its field may be widened, that a greater range of adhesions now regarded as indivisible and some difficult adhesions now attacked thoracoscopically with misgiving may instead be decollated extrapleurally and that timid patients may take courage in feeling that one further possibility exists for them between a failed thoracoscopy and the loss of their ribs.

SUMMARY

A technique is described for decollating intrapleural adhesions by open extrapleural pneumonolysis with the maintenance of an essentially intrapleural artificial pneumothorax.

Four cases are reported.

The thoracoscopic and extrapleural operations were performed in Dunedin Hospital by Mr. James A. Jenkins and Mr. Stanley L. Wilson, with both of whom the decollation technique was developed in close association.

REFERENCES

1. Allbritten, F. F.: Practice of Surgery, ed. D. Lewis, Hagerstown, Md., 1944, vol. V, p. 35.
2. Eloesser, L., and Brown, P. K.: Amer. Rev. Tuberc. 8: 519, 1924.
3. Georgocopoulos, G.: Arch. Tub. Sismanoglion Inst. 3: 333, 1947.
4. Kunstler, W. E.: J. THORACIC SURG. 16: 353, 1947.
5. Rafferty, T. N.: Artificial Pneumothorax, in Pulmonary Tuberculosis Including Its Relationship to the Broader Aspects of Collapse Therapy New York, 1944, Grune & Stratton.
6. Sellors, T. H.: Thorax. 2: 218, 1947.
7. Simmonds, F. A. H., and Hounslow, A. G.: Tubercle. 22: 66,. 1941.

MEDIASTINAL TUMORS OF BLOOD VASCULAR ORIGIN

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This report deals with three surgical cases of mediastinal tumor in which the histologic picture was that of hemangioma or hemangio-endothelioma. These lesions were encountered among approximately two hundred mediastinal tumors treated surgically at the Mayo Clinic prior to Jan. 1, 1947. In addition, accounts of all mediastinal tumors of probable blood vascular origin in the available literature have been sought. Though no claim to completeness can be entered because of the extensiveness of the literature on mediastinal tumors in many languages and in many publications not generally available, a systematic and prolonged search yielded fourteen cases in which sufficient data were presented to make them acceptable as cases of probable blood vascular tumors of the mediastinum. The criteria for inclusion in this series were (1) location of the tumor in the mediastinum, (2) absence of a tumor in the lungs, (3) pathologic verification by post-mortem examination or by surgical exploration, and (4) the histologic picture of blood vascular spaces lined with endotheliomatous tumor cells. A conscientious effort has been made to avoid the error of including in this group highly vascular malignant tumors that were not of vascular origin.

Perhaps because of the protean nature of tumors in the mediastinum and even more because of the striking train of symptoms that results from progressively enlarging tumors in certain parts of the mediastinum, the literature abounds with reports of mediastinal tumors long before the introduction of the roentgen ray, which made reasonably early diagnosis possible, and, of course, long before the surgeon had successfully entered the chest for the removal of a tumor. In this early period, mediastinal tumors were generally considered to be malignant and were classified in two groups: carcinoma and sarcoma. The sarcomas were the more common, and they fall into the groups we recognize today as lymphoblastomas. The carcinomas were only slightly less common. They were usually thought to be primary in the mediastinum and frequently, as a terminal event, to invade the hila of the lungs. Many of these lesions described in detailed case reports of the last century we recognize today as primary bronchiogenic carcinomas which had invaded mediastinal nodes extensively and in which the secondary deposits of the tumor overshadowed the primary lesion. Occasionally, benign tumors were found and described. The dermoid cyst which today we classify as a dermoid type of teratoma received much attention and was occasionally recognized during life on the basis of the rather startling appearance of hair in the sputum.

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Our knowledge of the pathology of mediastinal tumors has advanced rapidly in the past twenty-five years following closely in the wake of new knowledge of respiratory physiology that has enabled the anesthetist to control respiration in the presence of an open pneumothorax and the surgeon to attack boldly and confidently an ever-increasing variety of lesions in the chest.

The ability of the surgeon to remove, with reasonable safety, circumscribed lesions within the mediastinum has made accurate knowledge of the variety and of the natural history of these lesions essential for an intelligent approach to the problem presented by a patient with an intrathoracic tumor.

Roentgen-ray examination of large numbers of apparently healthy persons has disclosed many mediastinal and other intrathoracic lesions which went undiagnosed in the past because symptoms are uncommon in the early life of these tumors. Successful surgical removal of many such lesions has permitted valuable pathologic and clinicopathologic studies, but since our knowledge of these tumors is still young and incomplete, reports of unusual and rare lesions make worth-while contributions to our rapidly accumulating knowledge in this field.

A number of excellent reviews of the subject of mediastinal tumors in general have been published recently[1, 2] and the experience of thoracic surgeons in the armed forces of the United States in World War II has been responsible for a number of interesting reports[3, 4, 5] concerning the incidence of mediastinal tumors in large numbers of young men and women undergoing roentgen examination of the chest and concerning the relative incidence of the several pathologic varieties. In the monograph of Heuer and Andrus[1] mediastinal tumors of blood vascular origin were not mentioned. In one hundred and nine mediastinal tumors removed surgically and reported on by Blades[3] there was no example of a tumor of blood vascular origin, and in thirty-three cases reported on by Watson and Diamond[4] there was a single instance of hemangioma of the mediastinum (Table I).

In 1944 Adams and Bloch[6] reported a case of hemangioma of the mediastinum (Table I). They were able to find but one previously recorded case (Winkelbauer's[7]) in the literature. Our own extended search uncovered a few more cases which we think should properly fall in this group, but at the same time it served to reemphasize the rarity of these lesions.

Among approximately two hundred mediastinal tumors that were removed surgically at the Mayo Clinic prior to Jan. 1, 1947, there were three which seem to satisfy the criteria we previously set forth for a mediastinal tumor of vascular origin. In Table I we have summarized the reports on the fourteen cases we have been able to collect from the literature and the data on the three cases of our own. Brief accounts of each of the latter three follow. The case numbers correspond to those in Table I.

REPORT OF CASES

CASE 15.—A 27-year-old man registered at the clinic on Sept. 15, 1941, complaining of a feeling of pressure in the chest of three weeks' duration. According to his account he had been in good health until eight months before, when he began to lose weight. Four months later he had chills, fever, and generalized pains. During the two weeks these acute symptoms

TABLE I. SUMMARY OF REPORTS OF CASES OF MEDIASTINAL TUMORS OF BLOOD VASCULAR ORIGIN

CASE	AUTHOR; YEAR	SEX	AGE, YEARS	PATHOLOGIC DIAGNOSIS	EVIDENCE OF MALIGNANCY			OUTCOME	PHOTOMICROGRAPH
					HISTOLOGIC	INVASIVENESS	METASTASIS		
1	Heuer,[13] 1924	M	33	Endothelioma (needle biopsy)	Yes	Yes	?	Died 4 months after operation	No
2	Heuer,[13] 1924	F	17	Pleural endothelioma	Yes	No	No	Living and well, 2 years	Yes
3	Hosoi and Stewart,[11] 1931	F	61	Malignant endothelioma	Yes	No	No (autopsy)	Died 27th hospital day	Yes
4	Lilienthal,[15, 16] 1927	F	4	Angiosarcoma? Hemangiosarcoma	Yes	Capsule posteriorly	No	Living and well, 10 years. Tumor disappeared on roentgenogram	Yes
5	Bencini,[17] 1936	—	18 days	Angioma	?	?	?	Died aged 18 days. Referred to by Bergstrom	No
6	Döderlein,[18] 1938-39	—	Premature infant	Hemangioma	?	?	?	Referred to by Bergstrom. Death in a few days	No
7	Bergstrom,[19] 1945	F	3.5 weeks	Hemangioma	No	Yes	No	Death in 4 weeks	Yes
8	Bergstrom,[19] 1945	F	5 weeks	Hemangioma	No	Yes	No	Death in 2 days	Yes
9	Adams and Bloch,[6] 1944	M	34	Hemangioma	No	Yes	No	Living and well, 4 years. Incomplete surgical removal	Yes
10	Winkelbauer,[7] 1920	M	29	Malignant hemangio-endothelioma	No	No	Yes	Died 2 months after operation. Local recurrence and metastasis	No
11	Kott,[20] 1922	F	36	Angiosarcoma	Yes	Yes	Yes	Died 7 months after first visit	No Postmortem histopathologic description
12	Stewart,[21] 1888	M	32	Angiosarcoma	Yes	Yes	Yes	Died 8 months after onset	Yes Complete postmortem description
13	Watson and Diamond,[4] 1947	—	—	Hemangioma	—	—	—	Not given	No
14	Shennan,[12] 1914	F	23	Angioma	No	Yes	Yes	Died	Yes
15	Authors, 1948	M	27	Hemangio-endothelioma	Yes	Yes	Yes?	Died 2 months after exploration	Yes
16	Authors, 1948	M	18	Hemangio-endothelioma	Yes	Yes	No	Living and well 3.5 years after operation	Yes
17	Authors, 1948	M	59	Hemangioma	No	No	No	Living and well 14 months after operation	Yes

were present, he was irrational part of the time. A roentgenogram of the chest revealed a tumor which was said to displace the trachea and the heart. For this he was given a course of deep roentgen-ray therapy which, according to his story, was followed by some regression in the mass. Three weeks prior to his registration at the clinic, a sensation of pressure in the chest, a cough productive of thick, mucoid sputum, night sweats, dyspnea on exertion, and anorexia had developed. He had lost thirty pounds (13.6 kilograms) since the onset of his illness.

The past history and family history were not significant.

On physical examination he was found to be thin and pale. The blood pressure was 124 systolic and 68 diastolic, expressed in millimeters of mercury. The pulse rate was 112 per minute and the oral temperature 99.3° F. During the course of the examination there were frequent paroxysms of coughing. Examination of the chest revealed signs of consolidation in the left side with shift of the heart and mediastinum to the right.

A roentgenogram of the chest showed a circumscribed shadow lying anterior to the left pulmonary hilum between the second and fourth ribs (Fig. 1, *a* and *b*). Roentgenoscopic examination yielded the additional information that the mass did not have an expansile pulsation. Our films were compared with those that had been made by the patient's physician at home and some increase in the size of the tumor was apparent.

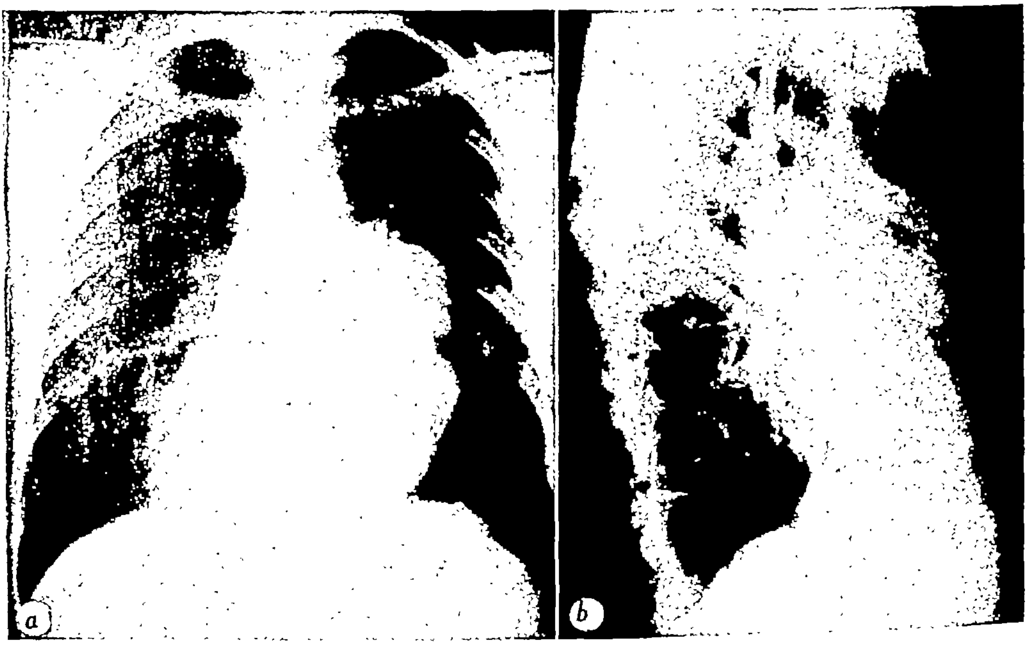

Fig. 1 (Case 15).—*a*, Posteroanterior view. *b*, Left lateral projection showing the anterior position of the mass.

Routine laboratory studies revealed normal urine, a moderate anemia, a normal leucocyte count, and a negative serum flocculation for syphilis.

Exploratory thoracotomy was advised and on Sept. 26, 1941, the left side of the chest was explored, an anterior approach being used. A huge, obviously malignant tumor practically filled the entire mediastinum, compressing the left lung laterally and pushing the heart to the right. The tumor was invading the pericardium and structures in the anterior mediastinum, and it could not be removed. Biopsy revealed hemangio-endothelioma, grade 1 (Broders) (on a basis of 1 to 4, in which 1 represents the least and 4 the most malignant condition) (Fig. 2).

Postoperatively, the patient failed rather rapidly. There were signs of progressive superior vena caval obstruction, pain was severe, and death came on Dec. 1, 1941, after his return home. Post-mortem examination was not done, but an account of the manner of his death in a letter from his wife suggested that cerebral metastasis probably had developed as a terminal event.

Microscopic Description.—Histologically, the lesion had the appearance of a capillary hemangio-endothelioma (Fig. 2, *a* and *b*). Most of the spaces were empty, but a few were filled with blood. These spaces were lined with round cells. In some areas sheets of endothelial cells replaced the vascular spaces. There was moderate pleomorphism. Mitotic figures were scarce. There were areas of necrosis and fibrosis, and a number of deposits of hemosiderin. The pathologic diagnosis was hemangio-endothelioma, grade 1.

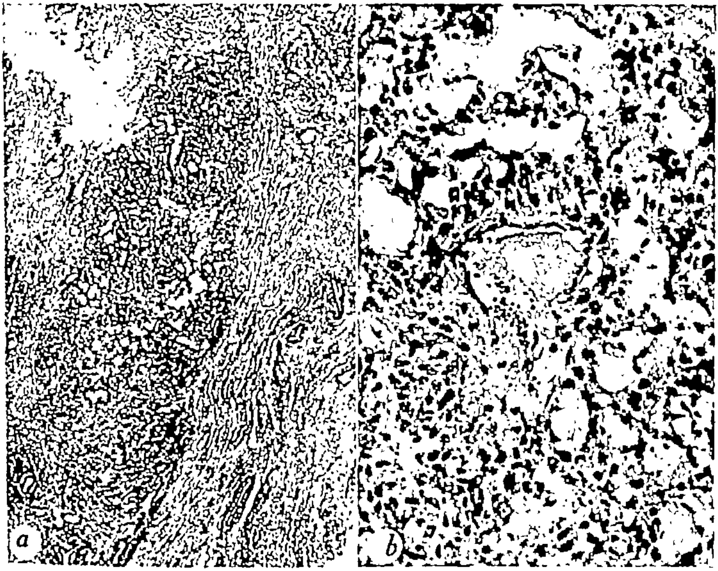

Fig. 2 (Case 15).—*a*, Section of biopsy specimen (hematoxylin and eosin ×26). *b*, Same section as in *a*, showing vascular spaces and large endotheliomatous cells (hematoxylin and eosin ×200).

Case 16.—An 18-year-old boy registered on March 31, 1944, because of a tumor in the right side of the chest which had been found on roentgen-ray examination at an army induction center in October, 1943. Since the age of 9 or 10 years he had occasionally experienced a dull, aching pain in the region of the third and fourth lumbar vertebrae. During the previous two years this pain had become more severe, and in addition, he had experienced recurrent, severe, sharp pain beginning in the right upper abdominal quadrant under the costal arch and extending across the abdomen. During these two years he had lost ten pounds (4.5 kilograms), but his general health had been good.

The family history and the past history were not significant.

The physical examination gave essentially negative results. The blood pressure in the brachial artery was 120 systolic and 70 diastolic. The pulse rate was 68 per minute and the temperature 98.4° F. Physical and roentgenologic examinations of the spinal column resulted in a diagnosis of spondylolisthesis. The pain in the back was ascribed to this defect.

A roentgenogram of the chest showed a rounded mass approximately 2.5 inches (6.4 cm.) in diameter in the right posterior part of the chest adjacent to the spinal column at the level of the ninth and tenth thoracic vertebrae (Fig. 3, *a* and *b*). There was some erosion of the tenth rib. Roentgenograms made in October, 1943, were available for comparison; no real change was apparent. A tentative diagnosis of mediastinal neurofibroma was made and thoracotomy was advised.

On April 19, 1944, right thoracotomy was done through a posterolateral incision along the ninth rib, the greater part of which was excised subperiosteally. There was a large, well-circumscribed tumor lying in the posterior costovertebral sulcus extending from the upper edge of the ninth rib at its attachment to the vertebral body to a level slightly below the eleventh rib. The tumor was external to the pleura and there were many large, tortuous vessels, both arteries and veins, lying on its surface. The tumor was visibly and palpably expansile. When the pleura overlying it was incised and mobilization of the lesion was begun, bleeding was profuse and difficult to control. The tumor itself was quite friable and vascular. Hemostasis was accomplished by controlling all vessels, including the underlying intercostal vessels at the circumference of the tumor. There was no gross evidence of invasion of structures in the intercostal spaces or of the ribs. The bed of the tumor was covered with pleura. The lung was inflated, and the thoracic wall was closed. The patient received 1,750 c.c. of whole blood during the course of the procedure.

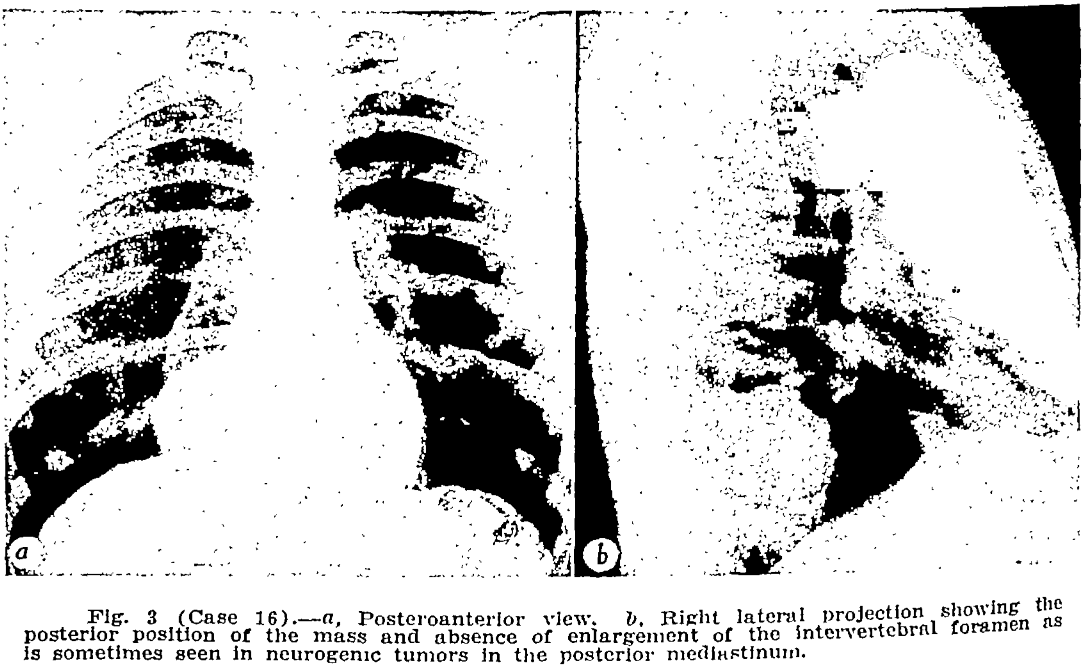

Fig. 3 (Case 16).—*a*, Posteroanterior view. *b*, Right lateral projection showing the posterior position of the mass and absence of enlargement of the intervertebral foramen as is sometimes seen in neurogenic tumors in the posterior mediastinum.

After the operation the patient made a rapid and uncomplicated recovery. He was dismissed from the hospital on his twenty-first postoperative day. Because of the histologic character of the tumor, roentgen-ray therapy was given postoperatively.

Pathologic Description.—The tumor was oval and measured 5 by 4 by 7 cm. In cut section it was quite vascular, and there were numerous areas of hemorrhage and necrosis. It was well circumscribed, and its capsule was complete except at the site of rather broad attachment to the thoracic wall (Fig. 4).

Multiple blocks from widely separated parts were taken for microscopic study. Histologically, the tissue had a capillary and cavernous pattern (Fig. 5, *a* and *b*), and in some areas the vascular spaces were replaced by sheets and columns of endothelial cells. Most of these cells were round, but some were inclined to be spindle-shaped and to line spaces, some

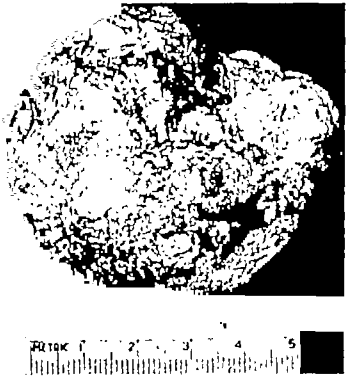

Fig. 4 (Case 16).—Surgical specimen.

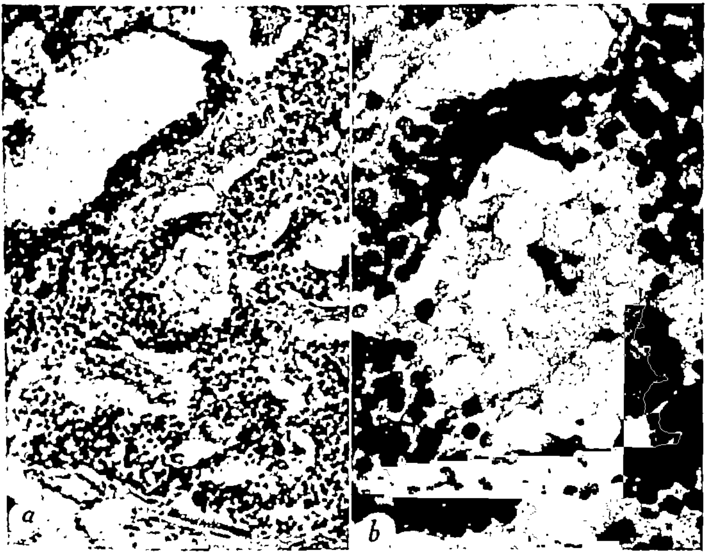

Fig. 5 (Case 16).—*a*, Demonstration of capillary and cavernous vascular pattern (hematoxylin and eosin ×135). *b*, Same section as in *a* (Hematoxylin and eosin ×435).

of which contained blood; mitotic figures were scarce and nucleoli were not prominent. Hyperchromatism and irregularity in size of the nuclei existed in moderate degree. There were numerous fibrous trabeculae throughout the tumor.

In one place, invasion of a thoracic sympathetic ganglion by the tumor was apparent (Fig. 6, *a* and *b*).

In a letter dated April, 1947, the patient reported that he had been in good health since his dismissal here three and one-half years previously.

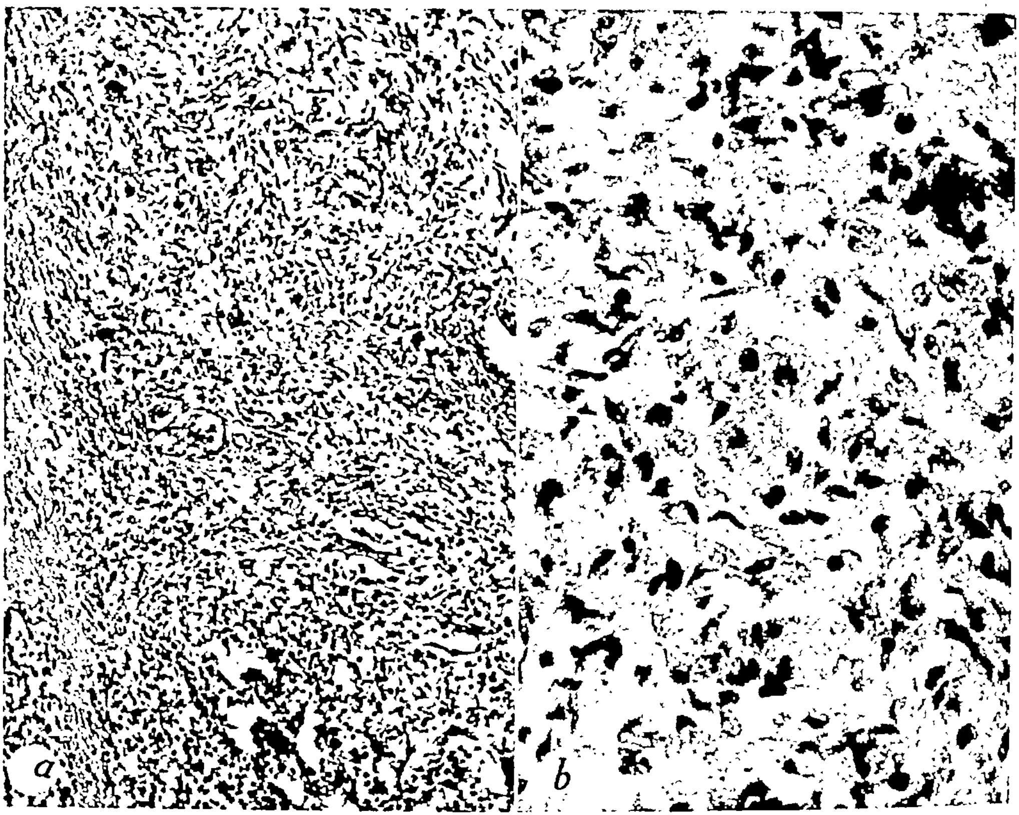

Fig. 6 (Case 16).—Sympathetic ganglion cells surrounded by tumor tissue. Stained with hematoxylin and eosin. *a*, ×90. *b*, ×365.

CASE 17.—A 59-year-old man registered at the clinic on Sept. 19, 1946, because of a tumor in the chest that had been discovered on roentgen-ray examination during the course of a routine clinical examination five months before. There had been no change in his general health and no local symptoms. The family history and past history were not significant.

On physical examination he was found to weigh 150 pounds (68 kg.). The blood pressure in the arms was 130 systolic and 88 diastolic; the pulse rate was 80 per minute and the temperature 99° F. He was well developed and well nourished. The only abnormal findings were bilateral inguinal herniae and varicosities of the saphenous veins.

Roentgenograms of the chest revealed a rounded, well-circumscribed mass approximately 3 cm. in diameter which appeared to be in the superior division of the right lower lobe (Fig. 7, *a* and *b*). There were several small calcified hilar lymph nodes in the left lung. Roentgenograms of the thoracic part of the spinal column showed minimal hypertrophic arthritic changes.

Urinalysis and routine examination of the blood, including determination of hemoglobin and erythrocyte and leucocyte counts, did not yield any abnormal data. The serum flocculation test for syphilis gave negative results.

A clinical diagnosis of intrathoracic neurofibroma was made and thoracotomy was advised.

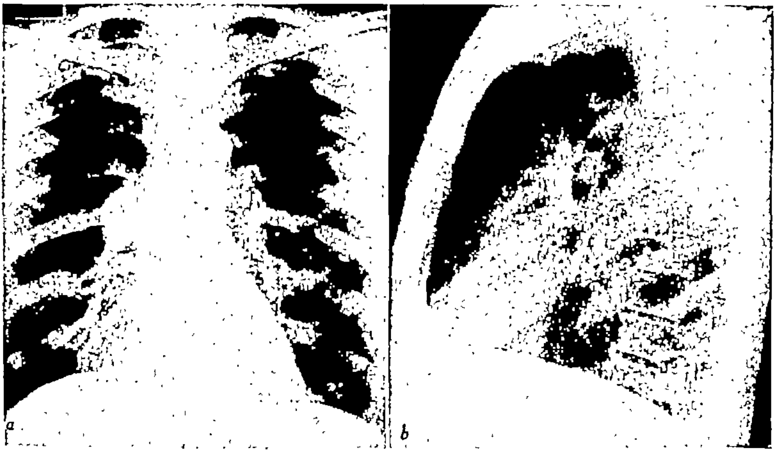

Fig. 7 (Case 17).—*a*, Posteroanterior view showing the mass in the region of the right pulmonary hilum. *b*, Right lateral projection showing the posterior position of the tumor.

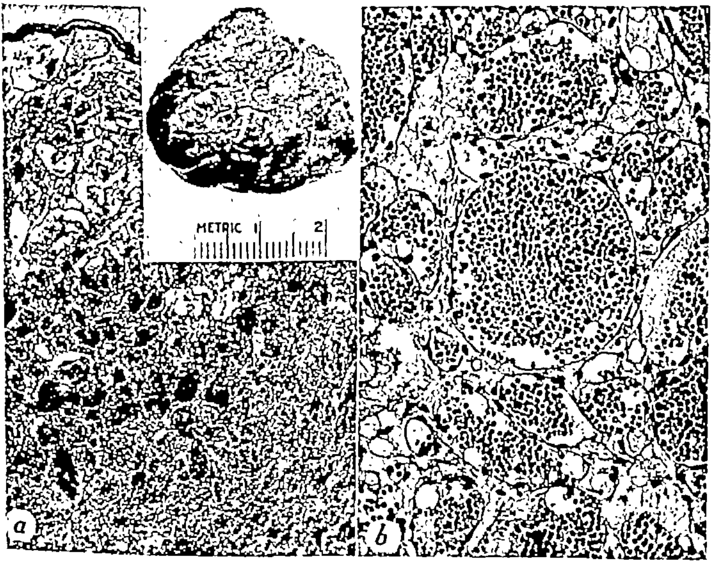

Fig. 8 (Case 17).—*a*, Capillary and cavernous hemangioma (hematoxylin and eosin ×25). *b*, Same section as in *a* (hematoxylin and eosin ×200). *Inset.* Well-encapsulated hemangioma.

On Oct. 19, 1946, the right chest cavity was explored through the bed of the seventh rib. There was a soft, purple, obviously vascular tumor arising in the region of the seventh interspace posteriorly, about 1.5 inches (3.8 cm.) from the spinal column. It was extrapleural and well encapsulated, and it was removed in toto without difficulty. Some oozing of blood from the bed of the tumor was controlled with mattress sutures. The intercostal vessels in the corresponding interspace did not appear dilated after the tumor was enucleated, the defect in the pleura was closed, the lung was inflated, and the thoracic wall was closed in layers without drainage.

The cut surface of the tumor was dark red and spongy in appearance. No large vessels could be identified in the pedicle. The tumor measured 3.5 by 3.7 by 2.5 cm. and weighed 12 Gm. (Fig. 8, *inset*).

Microscopic Anatomy.—There were many capillary and cavernous spaces, most of which were filled with blood (Fig. 8, *a* and *b*). In some of these spaces endothelial cells seemed to be piled up two and three deep, but in most they formed a single layer. The endothelial cells tended to be spindle shaped. No mitotic figures were found, and the hemangiomatous tissue was intersected by a few fibrous trabeculae. The pathologic diagnosis was hemangioma.

In a letter dated Dec. 5, 1947, the patient stated that he was well and free of symptoms.

COMMENT

In the experience of the surgeons at the Mayo Clinic, the most common primary tumors of the mediastinum are benign lesions, and in order of frequency they are tumors of nerve origin (neurofibroma, ganglioneuroma), teratoid tumors, and mediastinal cysts. Uhrich[8] studied 160 primary mediastinal tumors removed surgically at the clinic prior to Jan. 1, 1945. The pathologic classification and relative incidence are shown in Table II. These figures agree rather closely with those published by Blades,[3] Watson and Diamond,[4] and others.[1, 2, 5]

TABLE II. PRIMARY MEDIASTINAL TUMORS TREATED SURGICALLY (UHRICH)

BENIGN		MALIGNANT	
TYPE OF LESION	CASES	TYPE OF LESION	CASES
Primary nerve tumor	53	Thymoma	17
Teratoid tumor	29	Miscellaneous	7
Mediastinal cyst	18	Chondrosarcoma	6
Fibroma	5	Hemangio-endothelioma	4*
Chondromatous tumor	5	Teratoid tumor	4
Thyroid adenoma	3	Bronchiogenic cyst	1
Lipoma	2	Neurofibrosarcoma	1
Myxoma	1	Fibrosarcoma in a fibroma	1
Hamartoma	1	Liposarcoma	1
Parathyroid adenoma	1		
Total	118	Total	42

*Two of these cases are included in the present report (Cases 15 and 16). The data in the other two cases were reviewed by us and the lesions were reclassified as extremely vascular undifferentiated malignant tumors.

By all accounts, tumors of blood vascular origin in the mediastinum are rare. Though benign hemangiomas occur rather commonly in the skin and in many of the abdominal organs, hemangio-endotheliomas are rather uncommon in all situations. Furthermore, the tumors that have been classified as hemangio-endothelioma and endothelioma form a heterogeneous and controversial group. There are a number of factors which make classification difficult. As Ewing[6] has stated, "the demands for nutrition in rapidly growing cellular tumors may produce a type of growth which is composed chiefly of blood vessels sheathed by masses of tumor cells, and which is often called perithelioma, or telangiectatic sarcoma. This rather characteristic structure is not confined to any one class of tumors and it is not essentially a tumor of blood vessels.'' He defines true angiomas as ''a larger class of tumors in which a neoplastic process affects the walls of vessels and usually also the supporting connective tissue.'' Ewing's concept of endothelioma is also that which has been widely held, and his definition and discussions describe lucidly the complexity of the group and the controversial issues. ''The term endothelioma is applied to an extensive group of tumors which are believed to be derived from the living cells of blood vessels, lymph vessels and spaces, subdural spaces, and serous cavities.

''The scope of endotheliomas has suffered wide fluctuations because of the uncertainty surrounding the embryonal relations of different classes of endothelial cells, the peculiar position occupied by these cells as intermediate between epithelium and fibroblasts, and the difficulty of determining the origin of many tumors supposed to belong to this class. Thus some authors find the group extremely numerous and complex, while others, insisting upon more rigid data, describe a restricted class of tumors as endothelioma.'' This quotation has been taken from Ewing in order that we may clearly and unmistakably present the concept we have accepted and tried to adhere to in presenting the reports of our three cases and in searching the literature for others. According to our concept, endotheliomas comprise a very limited group, and hemangio-endotheliomas comprise, of course, an even more narrow and less numerous one. We have tried to limit ourselves to those tumors in which the evidence supported a blood vascular origin. Our definition agrees closely with that of Bell[10] who defined hemangio-endothelioma as a form of angioma comprised of blood vessels in early stages of formation. Blood does not necessarily circulate through the vessels of the tumor since they are incompletely differentiated. In incompletely differentiated parts of the tumor the endothelial cells form sheets or cords. In other parts of the tumor, numerous endothelial-lined spaces are present and blood is commonly found in a number of them. Histologic evidence of malignancy is judged on the basis of lack of cell differentiation, the number of mitotic figures, and the invasion of contiguous tissues.

The diagnosis of a simple cavernous and capillary hemangioma offers little room for error or for controversy.

Malignant tumors of blood vascular origin which metastasize to other parts of the body are very rare. Benign hemangiomas, on the other hand, are rather common. They may be localized and well circumscribed, or they may grow slowly and invade contiguous tissues.[11] The majority of multiple hemangiomas are multiple primary growths and not metastatic tumors, since the individual tumors are histologically benign[10]; however, histologically benign, metastasizing angiomas perhaps do occur.[12]

In our two cases in which the diagnosis of hemangio-endothelioma was made there was histologic evidence of malignancy and there were gross evidences of invasiveness in one instance and microscopic evidence of invasiveness in the other. One of these patients who had a lesion which was locally inoperable died a few months later apparently as a result of the neoplasm. The second patient survived more than three years without evidence of recurrence or distant metastasis. Our third patient had a neoplasm that grossly and microscopically was benign. He survived operation and was in good health when last seen more than a year after operation.

Symptoms and Signs.—The clinical picture presented in each of the seventeen cases (Table I) varied widely and was dependent as it always is in mediastinal tumors, on the size and the position of the growth. Symptomatically, there was nothing unique or unusual in the majority of cases. There were at least two exceptions to this statement, however. The patient reported by Lilienthal[15, 16] (Case 4, Table I) had a very unusual story, but rare cases of disappearance of a malignant lesion and long survival of the patient have been reported in carcinoma of the stomach, colon, breast, and other organs. The other exception was the presence of a palpable pulsation or an audible bruit over the tumor in three cases. These signs, of course, are not pathognomonic, for they are more common in the presence of an aneurysm or an arteriovenous fistula. Pain was usually the result of malignant invasive lesions. Respiratory embarrassment followed involvement of the pericardium or diaphragm, or the displacement of a large volume of pulmonary tissue. At least three of the lesions were discovered on routine roentgen-ray examination of the chest. As with any mediastinal tumor, cough, and hoarseness may be present, and they may signify involvement of the tracheobronchial tree and the left recurrent laryngeal nerve, respectively.

All subdivisions of the mediastinum were involved with apparently equal frequency.

Sex and Age.—In the seventeen cases available for analysis in this review, there was equal sex distribution, and the lesion was predominantly one of young individuals. Fourteen of the seventeen patients were less than 41 years of age, and four were under 1 year (Table III).

TABLE III. SEX AND AGE OF 17 PATIENTS WITH MEDIASTINAL TUMORS OF BLOOD VASCULAR ORIGIN

SEX	CASES
Male	7
Female	7
Not stated	3
Total	17
AGE, YEARS	
Under 1	4
1-10	1
11-20	2
21-30	3
31-40	4
41-50	0
51-60	1
61-70	1
Not stated	1
Total	17

Extremes of age: premature infant to 61-year-old woman.

Behavior of the Tumors.—In eight of the seventeen cases, there was histologic evidence of malignancy. In six there was histologic evidence of benignancy and in three the available information was insufficient to permit independent interpretation. One of the lesions we are including in the benign group was reported simply as an hemangioma.[4] Definite evidence of distant metastasis existed in five cases, in two of which the primary lesion had the appearance of benignancy. In Table IV, these data together with simple figures on operability are summarized. In the attempt to evaluate the data on operability, it must be understood that the patients under consideration included infants and stillborn infants, along with several patients who succumbed to their lesions long before the contents of the thoracic cage were considered to be in the domain of the surgeon. These figures on operability, then, mean little and cannot be applied to clinical practice today.

TABLE IV. PATHOLOGIC CHARACTER OF MEDIASTINAL TUMORS OF BLOOD VASCULAR ORIGIN IN 17 CASES

	PATIENTS		
CHARACTER OF TUMOR	TOTAL	TREATED SURGICALLY	LIVING
Histologically malignant	8*	3	2
Evidence of metastasis	3		
Histologically benign	6	4†	2
Evidence of metastasis	2		
Histologically indeterminate on basis of available data	3		

PATHOLOGIC DIAGNOSIS IN ORIGINAL REPORTS

DIAGNOSIS	CASES
Endothelioma	1
Pleural endothelioma	1
Malignant endothelioma	1
Hemangiosarcoma	1
Angioma	2
Hemangioma	6
Malignant hemangio-endothelioma	3
Angiosarcoma	2

*Lilienthal's patient (Case 4, Table I) was living and well ten years after his original report. She had received no surgical treatment.

†In Case 13 no follow-up has been reported.

A brief statement as to the outcome in each of the six patients in whom surgical removal of the lesion was accomplished is given in Table V. Four of the six patients were alive and well at the time of the last available report. Two of these four had lesions which were histologically malignant. One was followed up twenty-four months and the other forty-two months. A third member of this group had a lesion which could not be removed completely because it had invaded the pericardium, though the histologic picture was that of benignancy. This patient was alive and well four years later, at the time of Adams and Bloch's report in 1944. Though the prognosis must remain guarded in these patients, the lesions commonly are of a low order of malignancy, and equally commonly, they are benign.

TABLE V. OUTCOME IN 6 CASES IN WHICH THE LESION WAS REMOVED SURGICALLY

CASE	OUTCOME
2	Patient living and well at last report two years postoperatively. Tumor was histologically malignant.
9	Patient living and well four years postoperatively. Tumor was invasive grossly but histologically benign.
10	Patient died two months postoperatively of local recurrence and metastasis.
13	No follow-up reported. Lesion was called benign hemangioma.
16	Patient living and well 42 months postoperatively. A recent roentgenogram of the chest failed to reveal evidence of local recurrence or pulmonary metastasis. Histologically, the lesion was malignant and had invaded a dorsal sympathetic ganglion.
17	Patient living and well 14 months postoperatively. Lesion was benign histologically and was called an hemangioma.

SUMMARY AND CONCLUSIONS

This report has dealt with three cases of mediastinal tumor in which the histologic picture was that of hemangioma or malignant hemangio-endothelioma; these three tumors were encountered among approximately 200 mediastinal tumors treated surgically at the Mayo Clinic prior to Jan. 1, 1947. A careful, though necessarily incomplete, perusal of the literature on mediastinal tumors brought to light reports of fourteen additional cases of blood vascular origin.

A studious attempt has been made to avoid the easy error of including any highly vascular malignant neoplasm in this group. Only those cases have been included in which the evidence for blood vascular origin of the tumor seemed reasonably complete.

Primary mediastinal tumors are uncommon; those of blood vascular origin are rare. The most frequent lesions among them are benign tumors of nerve origin and cystic lesions of teratomatous or enterogenous origin. Many other varieties have been reported.

In two of our three cases there was evidence of malignancy. One patient had a lesion that had invaded surrounding mediastinal structures and that was too extensive for surgical removal; the other had a lesion which was histologically of low-grade malignancy and which had invaded a contiguous sympathetic ganglion. The third patient had a benign hemangioma.

Of the fourteen cases gleaned from the literature there was evidence of malignancy in eight. In six of these the lesions were histologically malignant, and in two the lesions were called histologically benign but there were regional and distant metastases.

Of the entire group of seventeen patients, surgical removal of the lesion was accomplished in six; four of these six were living at the time of the last available reports. This cannot be interpreted in terms of operability for some of these patients came under observation long before lesions in the mediastinum were surgically accessible.

There is evidence to support the contention that so-called benign hemangiomas associated with metastatic tumors are in reality multiple primary lesions. The outlook for a patient with a single, well-encapsulated, histologically benign hemangioma of the mediastinum is probably excellent. Even when it is not well encapsulated and cannot be completely removed, the outcome is hopeful on the basis of the report of Adams and Bloch whose patient was alive and well four years after operation. The prognosis must be guarded in those patients who have a lesion with histologic features of malignancy, and the prognosis in the individual case cannot be predicted, as it almost never can be in neoplasms in any situation, on the basis of histologic appearance alone. Lilienthal's case rather dramatically illustrates the truth of this statement.

No mediastinal tumor produces a sufficiently distinctive clinical or roentgenologic picture to permit a consistently accurate pathologic diagnosis. Many of these tumors are malignant, others have malignant potentialities, and all should be removed surgically unless a definite contraindication exists.

REFERENCES

1. Heuer, G. J., and Andrus, W. DeW.: The Surgery of Mediastinal Tumors, Am. J. Surg. 50: 146-224, 1940.
2. Thompson, J. V.: Mediastinal Tumors and Cysts, Internat. Abstr. Surg. 84: 195-221, 1947.
3. Blades, Brian: Mediastinal Tumors; Report of Cases Treated at Army Thoracic Surgery Centers in the United States, Ann. Surg. 123: 749-764, 1946.
4. Watson, W. L., and Diamond, H. D.: Surgical Thoracic Tumors in Navy Personnel, J. Thoracic Surg. 16: 1-11, 1947.
5. Bradford, M. L., Mahon, H. W., and Grow, J. B.: Mediastinal Cysts and Tumors, Surg., Gynec. & Obst. 85: 467-491, 1947.
6. Adams, W. E., and Bloch, R. G.: Hemangioma of the Mediastinum; Report of a Case, Arch. Surg. 48: 126-129, 1944.
7. Winkelbauer, A.: Zur Frage der chirurgischen Behandlung der Mittelfellgeschwülste, Wien. klin. Wchnschr. 42: 650-652, 1929.
8. Uhrich, E. C.: Primary Mediastinal Tumors: a Histopathologic Study, Thesis, Graduate School, University of Minnesota, 1947.
9. Ewing, James: Neoplastic Diseases; a Treatise on Tumors, ed. 3, Philadelphia, 1928, W. B. Saunders Company.
10. Bell, E. T.: A Textbook of Pathology, ed. 4, Philadelphia, 1941, Lea & Febiger, p. 291.
11. Wright, A. W.: Primary Malignant Hemangioma of the Spleen With Multiple Liver Metastases, Am. J. Path. 4: 507-524, 1928.
12. Shennan, Theodore: Histologically Non-malignant Angioma, With Numerous Metastases, J. Path. & Bact. 19: 139-154, 1914-15.
13. Heuer, G. J.: Intrathoracic Tumors; Experiences With 8 Cases of Tumor of Thoracic Wall Pleura and Mediastinum, Ann. Surg. 79: 670-686, 1924.
14. Hosoi, Kijoshi, and Stewart, F. C.: Differential Diagnosis of Mediastinal "Tumors"; Analysis of Eight Verified Cases, Arch. Int. Med. 47: 230-258, 1931.
15. Lilienthal, Howard: Mediastinal Sarcoma—Treated by Coley's Fluid, Ann. Surg. 85: 615-619, 1927.
16. Lilienthal, Howard: Hemangiosarcoma of the Mediastinum, Ann. Surg. 104: 1107-1108, 1936.
17. Bencini, Bruno: Quoted by Bergstrom, V. W.[19]
18. Döderlein, H.: Quoted by Bergstrom, V. W.[19]
19. Bergstrom, V. W.: Hemangioma of the Mediastinum Causing Death in the Newborn, New York State J. Med. 45: 1867-1871.
20. Kott, B.: Ueber Angiosarkome des Mediastinums, Deutsche med. Wchnschr. 2: 1042-1043, 1922.
21. Stewart, J. C.: A Case of Mediastinal Tumor (With Specimen), Northwest Lancet 8: 312-316, 1888.

MESENCHYMOMA OF THE PLEURA

A CASE REPORT

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REPORTS of primary pleural tumors are numerous, but observations and interpretations of these tumors continue to raise many perplexing questions.

Primary tumors of the pleura have presented an extremely varied histology (Robertson,[1] Stout[2]). They have been described as (1) combined sarcoma and carcinoma (sarcocarcinoma), (2) sarcoma, and (3) carcinoma. These differences in histology have led to extreme difficulty in relating the tumor to a specific tissue of origin. The elements most commonly considered as possible precursors of the various pleural tumors have been (1) the subpleural lymphatic vessels, (2) the subpleural connective tissue, and (3) the serosal lining cells or pleural mesothelium.

It can be readily surmised from these considerations that there are difficult problems confronting the pathologist in the identification and classification of pleural tumors in regard to histology and origin. Because classification depends partially upon accumulated observations, we are reporting a primary pleural tumor which has aroused considerable interest because of its peculiar position in the right upper interlobar fissure, its strange histology, and its probable histogenesis.

CASE HISTORY

R. S., an asymptomatic 51-year-old white man, a veteran of World War I, was admitted to the Brooke General Hospital on Jan. 14, 1946, having been referred to one of us (D. L. P.) by Dr. R. G. McCorkle of San Antonio, because of a tumor in the right lung. This tumor was first observed in 1942 when chest plates were taken during an attack of influenza associated with pain in the chest. At this time it was thought to be a cyst of the right lung. The patient remained asymptomatic, but a repeat chest x-ray examination in 1945 revealed that the mass had doubled in size. He was, therefore, admitted to the Brooke General Hospital for further observation and treatment. He had no complaints; he gave no history of cough, sputum, or fever. The patient's past history revealed that he had had pneumonia three times as a child. The last attack was in 1912, when he apparently had an associated empyema on the right. Subsequent to this time he had had influenza about once a year for the past four or five winters, but he had had no other complaints referable to the chest.

Physical and laboratory examinations were noncontributory.

Roentgenograms of the chest on Jan. 16, 1946, revealed a discrete oval shadow in the right mid-thorax measuring 6.5 by 9.0 cm., located in the anterior half of the thorax (Fig. 2). The margin was smooth and sharp. The appearance was interpreted to be that of a retention cyst. The rest of the chest was apparently normal.

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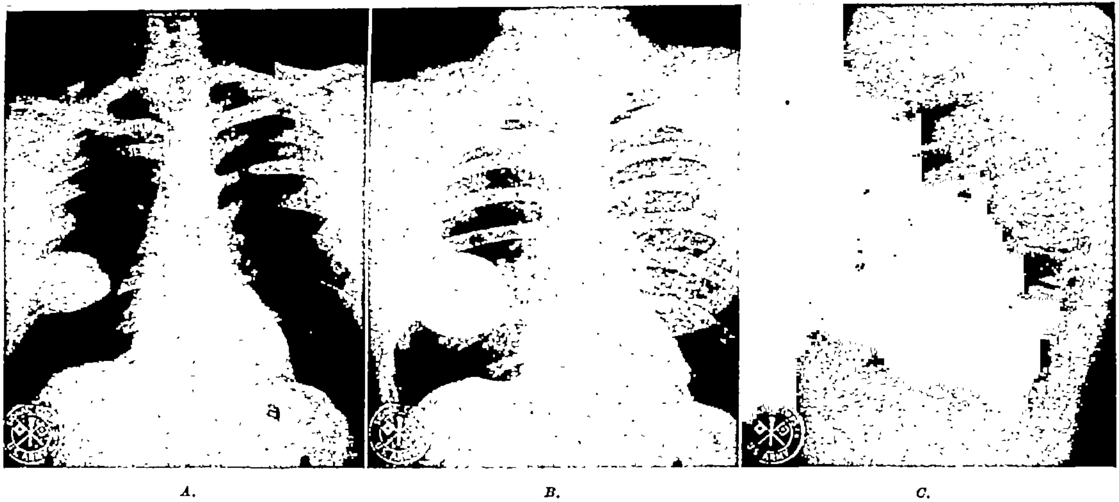

A. B. C.

Fig. 1.—*A*, Roentgenogram made in 1942. *B*, and *C*, Roentgenograms made in 1945 revealing the tumor in posteroanterior and right lateral exposures situated anteriorly. The tumor has increased in size.

A bronchoscopic examination revealed narrowing of the orifices of the bronchi to the middle lobe and the dorsal division of the lower lobe of the right lung.

Bronchography revealed minimal cylindrical bronchiectasis involving the basal portion of each lower lobe. There was nonfilling of the right middle lobe including the mass previously visualized. There was slight displacement of the bronchi about the mass.

Surgical exploration was advised, and on Feb. 19, 1946, one of us (D. L. P.) performed a thoracotomy and found a mass in the interlobar fissure completely surrounded by the right upper and middle lobes. The tumor was nodular, solid in consistency, and well encapsulated. The capsule was dissected free from the visceral pleura covering the upper and middle lobes to which it was markedly adherent. The tumor apparently derived its blood supply from the parenchyma of the middle lobe. Two moderate-sized vessels from the midde lobe were encountered during the dissection of the capsule. The tumor was completely removed with the capsule intact.

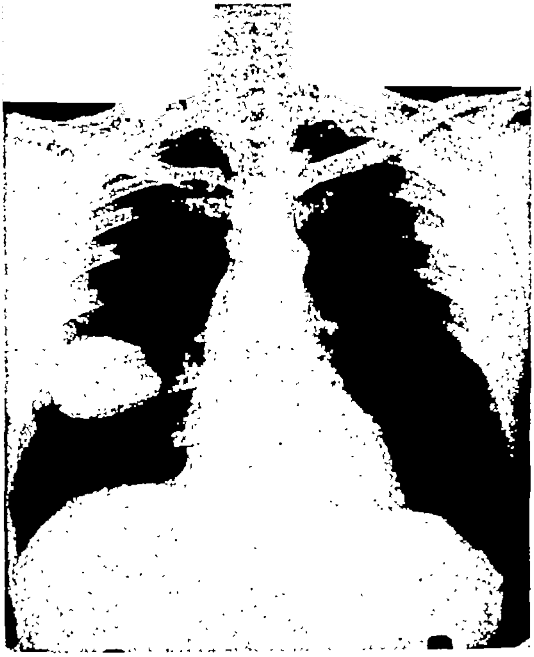

Fig. 2.—Posteroanterior roentgenogram of the chest revealing a discrete oval shadow measuring 6.5 by 9.0 cm., situated anterior in the right mid-thorax. (Brooke General Hospital, U. S. Army, Neg. 46-1444.)

The postoperative course was uneventful. The patient has been observed intermittently since his discharge from the hospital. He is in good health and has no complaints. Repeated examinations have revealed no evidence of recurrence of the tumor.

PATHOLOGY

The specimen consisted of a firm, nodular, slightly flattened oval-shaped mass measuring 10.3 by 3.5 by 7.5 cm. The external surface was completely covered by a thin, dull reddish brown capsule which was slightly roughened by numerous fibrous tags. The capsule bulged over nodules measuring from 0.1 to 4.5 cm. in diameter. The surfaces of these were relatively smooth, grayish white, and homogeneous. The intervening tissue was dark reddish brown connective tissue (Fig. 3).

The histology of the tumor as well as the cytology showed striking variations. The nodular areas observed grossly differed from the intervening tissue only in the degree of cellularity. The nodules themselves varied somewhat in cellularity. Some showed closely packed cell nuclei (Fig. 4, *A*). These were round to oval in shape and contained irregular networks of chromatin. A few contained nucleoli. Nuclear membranes were well defined. The nuclei varied slightly in size and shape. Many were quite pyknotic. A few mitotic figures were present. Cell borders were poorly defined. The cytoplasm was clear or vacuolated. The extremely cellular areas contained very little stroma. The less cellular areas showed a moderate amount of pink-staining fibrillar material running between the nuclei, staining as collagen. Some of this tissue was almost acellular (Fig. 4, *B*).

Numerous portions of the tumor were extremely vascular (Fig. 4, *C*). In areas where the amount of stroma predominated over the number of cells the perivascular areas were surrounded by a dense mantle of tumor cells. There were numerous spaces varying in size, filled with blood, and lined by tumor cells (Fig. 4, *D*).

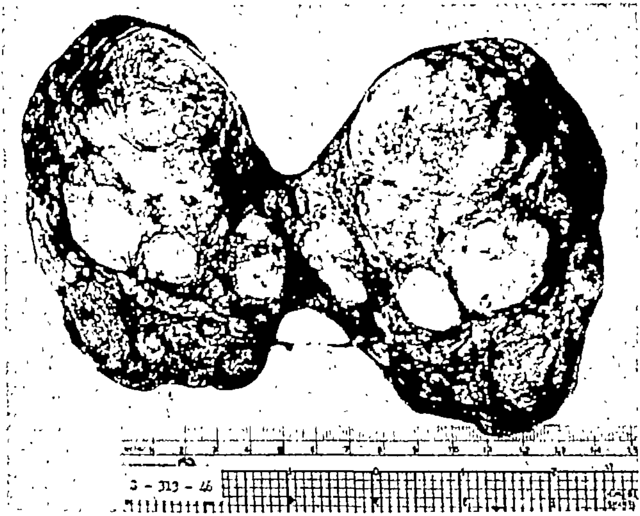

Fig. 3.—Gross appearance of the tumor. The mass was oval in shape and was made up of grayish white nodules of variable size separated by dark reddish brown connective tissue. (Brooke General Hospital, U. S. Army, Neg. 16-544.)

Several of the smaller nodules were made up of extremely large giant cells of irregular size and shape (Fig. 5, *A*). These giant cells often contained numerous multilobular nuclei with coarse networks and condensations of chromatin. The cytoplasm of these cells was more or less amphophilic and often contained very large, clear, well-circumscribed vacuoles. These vacuoles stained positively for fat with Scharlach R. The intervening stroma was made up of pale pink-staining homogeneous material.

The appearances thus far described characterized most of the tumor. However, there was one small area adjacent to the pleural surface which presented an entirely different structure. Here the histology consisted of numerous branching tubular structures lined by cuboidal cells showing round darkly staining nuclei and abundant neutrophilic cytoplasm (Fig. 5, *B*). The tubular structures were separated from one another by connective tissue stroma similar to that described above. Adjacent to this nodule the surface of the tumor was partially covered by intact serosal lining cells which dipped into the connective tissue forming crypts which bore an appearance identical to the tubular structures of the nodules described above (Fig. 5, *C*). Elsewhere, the surface of the tumor was also covered by prominent

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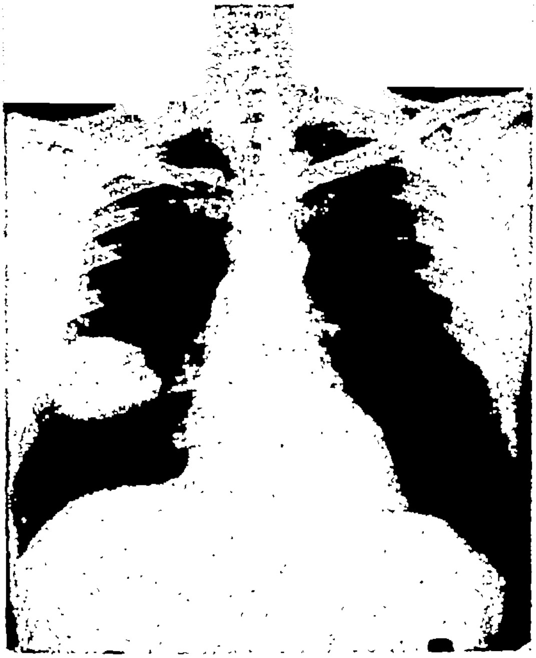

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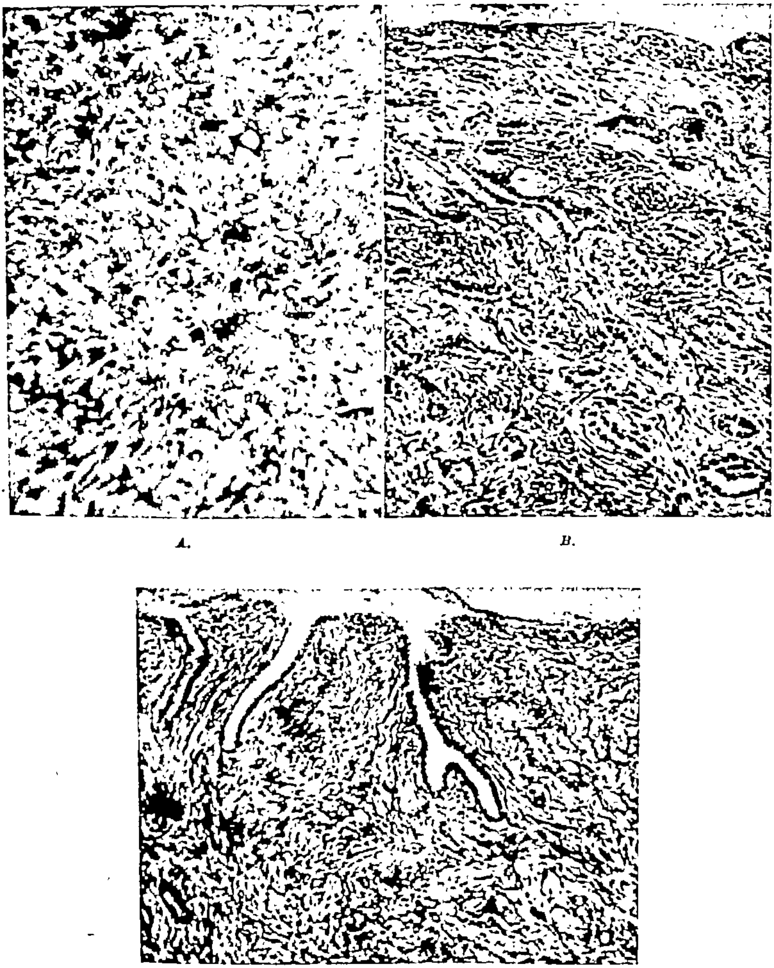

A.

B.

C.

Fig. 5.—Other sections of the tumor show: *A*, large multinuclear giant cells with vacuolated cytoplasm (possible lipoblasts); *B*, tubular structures lined by cuboidal cells from the serosal surface of the tumor; and *C*, intact serosal lining cells covering the surface of the tumor and dipping into the substance of the tumor forming crypts which resemble the tubular structures noted in the previous section, *B*. (Hematoxylin and eosin ×100.) Photos by U. S. Army Signal Corps.

intact serosal lining cells which were flat to tall columnar in shape, and orderly in arrangement. In no area was there any evidence that the serosal lining cells actually participated in the tumor process.

DISCUSSION

We believe that this was a connective tissue tumor. None of our observations suggested that this tumor was related to the subpleural lymphatic vessels. The only elements presenting an epithelioid appearance appeared to be nothing more than invaginations of pleural lining cells, which covered the tumor. Since these pleural lining cells—mesothelial cells—did not apparently participate in the tumor, we do not believe that a diagnosis of mesothelioma can be supported.

The microscopic observations indicated various phases of connective tissue differentiation. The numerous bizarre spaces lined by tumor cells and filled with blood appeared to be a part of the tumor process rather than a vascular reaction to the new growth. The unusual vacuolated giant cells had the appearance of lipoblasts.[3] In addition, there was fairly well-differentiated connective tissue showing definite production of collagen, which appeared to be neoplastic rather than reactive. All of these considerations lead to the suspicion that the precursor cell must have been one capable of producing these various elements. It follows, then, that the precursor cell in this tumor must have been the mesenchymal cell.[3]

Sections of this tumor were sent to Dr. Arthur Purdy Stout, who wrote as follows: "I agree with you that the glandlike structures are probably inclusions of pleural mesothelium and probably not an integral part of the neoplasm, since they are confined to only one small area near the pleura. This tumor is not exactly like the one described by Dr. Murray and myself[2] because it seems to have a greater variation in the mesodermal structures produced. As you quite justly remark, there are portions of this growth which look very much like neoplastic blood vessels and they are so numerous and bizarre that I cannot fail to suppose that they are part of the neoplastic growth. The area where the foamy giant cells are found suggests quite strongly the appearance of liposarcoma. The giant cells seem to me to be more than mere phagocytes; rather they are more probably lipoblasts. The amount of collagen and reticulin in this tumor is remarkably varied in quantity and thickness; moreover the arrangement of fibers and cells is very bizarre and does not reproduce the customary appearance of fibrosarcoma. If we are correct in supposing that this is a mesoblastic tumor which differentiates into lipoblasts, vascular structures and bizarre mesenchymal structures in different areas, then I think that this tumor belongs to a special variety of which I have been accumulating examples with the idea of classifying them all under the term 'mesenchymoma.' I know that this term has been used already with regard to ovarian neoplasms by Novak[4] but it has not met with general acceptance as applied to the ovary, and I think it can be used with much greater accuracy with a tumor such as this and others like it which, in addition to the structures seen in this tumor, also form atypical bone and cartilage."

Our final interpretations are that this tumor represents one which has differentiated into several types of connective tissue, and for this reason must have arisen from a multipotent primitive connective tissue cell, the *mesenchymal* cell (according to Dr. Stout). In multiple sections we were unable to recognize any participation in the tumor on the part of mesothelial cells, and for this reason see no indication to attribute the origin of the tumor to these cells. We realize that our lack of observation of mesothelial involvement does not completely rule this out as a possibility. It seems more probable to us however that this tumor arose in the subserosal connective tissue from the mesenchymal cell, occurring there either through lack of prior differentiation or through reversion of mature cells to this more primitive type.

SUMMARY

An asymptomatic 51-year-old white man presented himself for removal of a thoracic tumor which had been discovered incidentally on x-ray examination of the chest four years previously. During this interval of four years it had doubled in size. The tumor was removed. Pathology studies revealed a tumor made up of diverse connective tissue elements which suggested that its origin was from a multipotent mesenchymal cell. It apparently belongs to that group of tumors classified by Stout as mesenchymomas.

Two years after removal of the tumor, the patient is living a normal life, and is well. There is no evidence of recurrence of the tumor.

REFERENCES

1. Robertson, H. E.: "Endothelioma" of the Pleura, J. Cancer Research 8: 317, 1924.
2. Stout, A. P., and Murray, M. R.: Localized Pleural Mesothelioma, Arch. Path. 34: 951-964, 1942.
3. Stout, A. P.: Personal Communication.
4. Novak, E.: Gynecological and Obstetrical Pathology, Philadelphia and London, 1940, W. B. Saunders Company, p. 241.

USE AND ABUSE OF BRONCHOSCOPY IN ALLERGIC ASTHMA

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BRONCHOSCOPY is employed in bronchial asthma mainly for the purpose of differentiating it from other types of wheezing. Early advocates[1] of therapeutic bronchoscopy in allergic asthma observed that aspiration of the characteristic tenacious mucus benefits some patients considerably while in others in whom there is little secretion in the bronchial tubes, no improvement ensues. This experience is now shared by many.[2]

In 1938, I reported[3] that bronchoscopy had been a lifesaving procedure in several instances. It was then suggested that all asthmatic patients in a moribund state should be given the benefit of this treatment. Although an increasing number of clinicians[4] concur in this view, there is considerable reluctance on the part of both bronchoscopists and allergists to employ the procedure in an extreme emergency.* For this reason it was attempted to review the records of therapeutic bronchoscopies in 112 patients with allergic asthma with the view of setting up distinct criteria for the indication and contraindication of bronchoscopic therapy.

PATHOGENESIS OF ASTHMA

Before approaching the subject proper, brief reference to the mechanism of asthmatic attacks must be made. Asthmatic wheezing is effected by air passing through partially obstructed bronchi. This obstruction is caused by mucus as well as by bronchospasm which, as recent knowledge suggests, are due to histamine elaborated from the antigen-antibody reaction. From clinical experience it appears that the mucus becomes thicker in consistency and its expulsion more difficult, the more protracted the condition.† Wheezing and cough are relieved when some of the mucus is expectorated. Conversely, when elimination is interfered with (e.g. opiates), the attacks become more severe. An unusual degree of dryness of the respiratory surfaces further tends to make the mucus sticky and adherent to the bronchial walls. In this state the bronchial dilation brought about by the action of epinephrine and aminophyllin no longer suffices to loosen it up sufficiently for expectoration. These drugs are no longer effective (epinephrine-fast). The gluelike material behaves like a foreign body. It constitutes a check valve to the portion of the lung distal to it, allowing the air to enter during inspiration, but trapping it during the expiratory phase of the respiration.

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*This was recently brought out when three bronchoscopists refused to carry out the procedure in one of my patients dying from asthma, because they considered his condition "too far advanced." A fourth consultant finally performed the bronchoscopy, which was immediately followed by a dramatic recovery after 120 c.c. of thick mucus were aspirated from the bronchi.

†The changes in the appearance of the expectorated material resemble those seen in hay fever in which, at the beginning of the season, the nasal and sinus mucosa secretes a copious, watery fluid, that becomes thicker and purulent later on.

INDICATIONS

With this in mind, the principal reason for a therapeutic bronchoscopy in allergic asthma is to remove the thick, tenacious mucus which accumulates in the bronchial tree and interferes with respiration.

In practice, bronchoscopy should be employed: (1) To prevent a moribund patient from becoming asphyxiated through the accumulation of the mucus; (2) to break up a chronic asthmatic state—so-called status asthmaticus—regardless of its severity; (3) to remove a single mucous plug which, through complete obstruction of a bronchus, has produced partial or total pulmonary atelectasis; (4) to dilate strictures of the bronchi which follow inflammatory changes of the bronchial mucosa; (5) to remove mucous secretion from bronchiectatic areas.

1. *Emergency.*—Eight patients in this series of 112 (Table I) were in a moribund state. Either following sudden onset, or developing gradually, their condition had deteriorated in such a manner that it had become refractory to all medication. The expectoration, which had been without difficulties at first and had yielded copious and viscid material, had gradually "dried up" and become very laborious. In all but one patient (Case 2, to be described later) the main bronchi and secondary ramifications of the bronchial tree were completely obstructed by mucous plugs. After the removal of between 30 to 60 c.c. of this material through aspiration and lavage with saline solution, the asthma subsided.

Table I. Results of 144 Bronchoscopies in 104 Patients*

	TOTAL	EXCELLENT	GOOD	NO EFFECT
Emergencies	8 (11)	7 (10)	--	1 (1)†
Chronic asthmatic state including:	96 (132)	8 (8)	50 (75)	38 (49)
Bronchiectasis	Indefinite			
Atelectasis	4 (5)	3 (3)	--	1 (2)
Bronchostenosis	4 (6)	3 (3)	1 (3)	--
Total	104 (144)			

*While some of these patients remained free from asthma following the bronchoscopic treatment, the results represent only the short-term response to the treatment since permanent improvement might be attributable to measures employed previously.

Number of bronchoscopies indicated in parentheses.

†Case 2.

In one case (a 16-year-old girl), bronchoscopic treatment appeared to be lifesaving on four occasions. When, on admission to the hospital during another such extreme attack, the bronchoscopist was not immediately available, the patient died.

2. *Status Asthmaticus.*—By far the majority of bronchoscopies were carried out for the purpose of breaking up a chronic, not necessarily severe, state of asthma which did not yield to other modes of treatment. If the sputum of a chronic asthmatic patient presents bronchial casts, if each coughing spell results in severe wheezing which is somewhat relieved upon expectoration, or if there is evidence that "the mucus does not come up any more," bronchoscopic treatment should be considered. Upon endoscopic inspection, there is, in addition to the obstructing mucus, considerable narrowing of the bronchial

lumen; bronchospasm may actually be so severe that it may simulate a cicatricial stenosis; collapse of the posterior walls of the trachea and bronchi may be noted on expiration; the bronchial mucosa exhibits acutely inflamed areas which are interspersed with normal appearing ones. One hundred thirty-two bronchoscopies were performed on 96 patients (Table I). In eight, a single bronchoscopic treatment was followed by complete and lasting relief from asthma, and fifty additional patients improved considerably following one or more bronchoscopic treatments; the remaining thirty-eight experienced little or no benefit. Among the former there were several individuals in whom the asthma was aggravated, or induced, by psychogenic factors. Here marked bronchospasm was noted, but little or no mucous secretion was present in the bronchi. When the mucus is not completely removed through the bronchoscope or expectorated subsequently, patients may relapse into the asthmatic state after initial improvement. In this case it is advantageous not to wait longer than one or two days for a second bronchoscopic treatment in order to remove the mucus more thoroughly.

3. *Atelectasis.*—A single mucous plug may lead to either complete or partial atelectasis of a pulmonary lobe, according to whether a main or secondary bronchus is obstructed. The physical findings of suppression of breath sounds and vocal fremitus cannot be elicited as clearly here as in nonasthmatic individuals because of the marked wheezing throughout the lungs. Localized excessive wheezing about the atelectatic areas is a characteristic finding of diagnostic significance. Complete atelectasis of a single pulmonary lobe is not an uncommon complication of allergic asthma. In one of the four patients in this series the bronchoscopist did not succeed in eliminating the mucus and clearing up the atelectasis.

4. *Stricture of Bronchi.*—In three patients, an exceedingly chronic asthmatic state was accounted for by bronchostricture which originated from inflammation of the bronchial mucosa. Nonproductive cough, suppression of breath sounds and fremitus over the affected area, and febrile episodes due to localized pneumonitis characterize this condition. Here, too, wheezing around the affected areas in excess over that heard in other parts of the lungs is a significant diagnostic sign. X-ray findings are less conclusive than in atelectasis. In contrast to a much larger incidence of this condition suggested by Prickman and Moench,[5] the records of our series revealed only four cases in which bronchostrictures were demonstrated. Three patients with persistent asthma showed complete recovery following a single bronchoscopic dilatation of the stricture.

5. *Bronchiectasis.*—In my experience, permanent bronchiectasis is encountered less frequently as a complication of allergic asthma than the literature indicates. In every patient with protracted asthma one would expect some temporary widening of the terminal bronchi, considering the large amount and the consistency of the mucus found on bronchoscopy in the ramifications of the bronchial tree. Indeed, our experience on several patients bears out the fact that such temporary bronchiectasis is no longer in evidence after the attack has subsided.

If a bronchography with lipiodol is desirable when bronchiectasis is suspected, great caution should be used. Reactions are not uncommon; even exitus from this procedure has been reported.[6] Allergic patients may be sensitive to the contrast material. In other cases, the "crowding" of the oil into a bronchial tree, filled to capacity with mucus, may lead to asphyxiation of the patient.

CONTRAINDICATIONS

Bronchoscopic treatment should not be employed when there is little or no mucous secretion or when the sputum is thin and watery. This is true (1) in asthma of short duration where there is edema of the alveoli which is often followed by pneumonitis;[7] (2) in incipient asthma characterized by a nonproductive pertussis-like bronchitis[7] in which bronchoscopy reveals petechial hemorrhages, and occasionally urticaria-like edema of the bronchial mucosa; (3) in the sudden severe attacks (allergic shock) following injections, ingestion, or inhalation of antigens to which extreme sensitivity exists where thin mucous secretion in conjunction with bronchospasm dominates the clinical picture.

HAZARDS FROM BRONCHOSCOPY

The reluctance of bronchoscopists to avail themselves of this procedure more frequently in allergic asthma can be understood because asthmatic patients are more susceptible to emergencies than other individuals. Sensitivity to, and intolerance of, anesthetics and other drugs administered before and during the operation constitutes the principal source of danger.

Anesthetics.—On several occasions pharyngeal edema was encountered followed by dyspnea immediately after local application of cocaine or pantocain to the pharynx. If such signs of sensitivity to the anesthetic are recognized promptly, epinephrine, applied locally and injected subcutaneously in large doses (0.5 to 1.0 c.c.), supplemented by intravenous aminophyllin and antihistamines will avert disaster. Intolerance to local anesthetics, on the other hand, manifests itself through such premonitory symptoms as flushing of the face, twitching of the muscles of the extremities, extreme nervousness, sensations of "heat" in abdomen, stertorous breathing and, finally, convulsions.[8] Sodium pentothal,[*] administered intravenously, is considered a potent antidote.

Preoperative Drugs.—Among preoperative medications, allergic patients are particularly susceptible to hazards from opiates. Codeine, morphine, dilaudid, and Demerol, in my experience, have led to aggravation of asthma. One of the patients (Case 2, Mr. W. F., 57 years old) developed marked cyanosis, Cheyne-Stokes respiration, and cardiovascular collapse within ten minutes after the hypodermic administration of $\frac{1}{6}$ gr. of Pantopon. Two hours later a bronchoscopy yielded only small amounts of thin mucous secretion; there was no bronchospasm and the bronchial mucosa exhibited evidence of inflammation throughout. The patient died four hours later. The autopsy revealed bilateral bronchiectasis, pulmonary emphysema, marked edema, and congestion in the liver and spleen. It was felt that this fatality was the result of intolerance of Pantopon.

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[*] If this drug is employed as a general anesthetic, it should be used judiciously. In a patient (Mr. R. F.) who received an intravenous injection of 5 per cent sodium pentothal preceding the bronchoscopy, spasm of the epiglottis developed which threatened asphyxiation. Under great difficulties the surgeon succeeded in prying open the epiglottis with the bronchoscope and introducing the instrument into the brochus.

Endoscopic Medication.—Because of the hazard of sensitization, a warning should be given against introducing drugs into the bronchial tree. We have abandoned the use of cocaine, Argyrol, 2 per cent guaiacol, 10 per cent silver nitrate, 1 per cent mercurochrome, or 1 per cent menthol, which were advocated by Lukens and others.[1] We are also refraining from the use of sulfathiazole solution. Only penicillin and occasionally small doses of epinephrine are employed under the precautions outlined here.

4. *Other Accidents.*—Severe dyspnea and unproductive cough may occur within a short period after the bronchoscopy. This indicates that some of the tenacious material had been freed but is now blocking some of the bronchial passages. A fatality reported by Lell[2] might thus be explained. One should, therefore, be prepared to reintroduce the bronchoscope promptly for another aspiration in this emergency.

A rather unique accident was encountered during a bronchoscopy in a patient presenting a bronchostenosis (Mrs. K. S., aged 36 years). During the attempt to dilate the stenosed bronchus the dilating bougie was locked so tightly by the spastic contraction that it broke off upon withdrawal. The object was later removed uneventfully by thoracotomy. Since this operation, the patient has been free from asthma.

PRECAUTIONARY MEASURES

In order to minimize the hazards described here, the following suggestions are made regarding the technique of the bronchoscopic treatment: Little or no anesthesia should be employed. If the administration of 1½ gr. of phenobarbital before the operation should not suffice, a 2 per cent solution of pantocain may be sprayed into the pharynx. Sodium pentothal is kept in readiness for intravenous use should there be signs of intolerance to the local anesthetic. Before the bronchoscopy, one-half of a 3¾ gr. ampule of aminophyllin is given intravenously and $\frac{1}{20}$ c.c. of 1:1,000 epinephrine, subcutaneously, in order to decrease bronchospasm. Another one-half ampule of aminophyllin is held in readiness for administration during the operation should the bronchospasm remain excessive. Oxygen is continuously administered throughout the procedure. Saline solution is injected through the bronchoscope if the mucus is difficult to remove through aspiration. Only if necessitated by persistent bronchospasm, 0.1 c.c. of a 1:1,000 solution of epinephrine admixed to 30 c.c. of saline is instilled into the bronchi. Larger doses may lead to unpleasant retions from the pharmacologic action of the drug.

Before the bronchoscopy, an effort is made to determine by both history and intradermal skin tests whether or not sensitivity to penicillin exists. If it had been given previously, it should be kept in mind that the optimal time interval during which sensitization develops is between two to five weeks. In spite of the fact that its previous administration produced no ill effect, sensitivity to the drug should be reckoned with. A dose of 100,000 units in 20 c.c.

of saline is introduced through the bronchoscopy if warranted by the presence of marked inflammation of the bronchial mucosa.

SUMMARY

1. The chief indication for bronchoscopic therapy in bronchial asthma is the state of emergency which arises from the patient's inability to expel the characteristic thick, tenacious mucus which might lead to asphyxiation. In a moribund asthmatic patient, therefore, bronchoscopy is as obligatory a procedure as the removal of a foreign body from a bronchus or a tracheotomy in a patient about to become asphyxiated from diphtheria.

2. Other purposes of bronchoscopic treatment are the breaking up of a chronic state of asthma regardless of its severity, the relief of atelectasis, the dilatation of cicatricial bronchostricture, and, occasionally, the relief of bronchiectasis in asthmatic individuals.

3. This treatment is contraindicated in asthma of short duration, in asthma associated with allergic shock, and in other instances where there is no clinical evidence of mucous plugs.

4. The main hazards in bronchoscopy are sensitivity to, and intolerance of, anesthetics and medications administered before and after bronchoscopy, as well as medications introduced endobronchially. For this reason, little or no anesthesia is used, and only saline solution is employed for lavage of the bronchial tree.

5. Introduction of antibiotics into the bronchi may be desirable if infection is the dominant cause of the attacks. However, they should be used very judiciously and an attempt should be made to avoid reactions from sensitivity to them.

REFERENCES

1. (a) Weille, F. L.: Bronchoscopy in Asthma, J. Allergy 2: 206-207, 1932.
   (b) Lukens, R. M.: Bronchoscopy in the Treatment of Asthma, Laryngoscope 35: 227, 1936.
   (c) Clerf, C. H.: Present Status of Bronchoscopy in Bronchial Asthma, Ann. Int. Med. 9: 1050-1056, 1936.
   (d) Tucker, G.: Bronchoscopy in Pulmonary Diseases, Ann. Int. Med. 8: 444, 1934.
   (e) Prickman, L. E., and Vinson, P. P.: Bronchoscopy in Asthma, J. Allergy 4: 286-293, 1933.
2. (a) Van Loon, E. L., and Diamond, C.: Bronchoscopic Aspects of Asthma in Children, Am. J. Dis. Child. 63: 217, 1942.
   (b) Gompertz, J. L.: Bronchoscopy: Its Role in the Treatment of Asthma, California & West. Med. 58: 10-11, 1943.
   (c) Lell, W. A.: Bronchoscopy as an Aid in the Diagnosis and Treatment of Allergic Pulmonary Diseases, Arch. Otolaryng. 43: 40-58, 1946.
3. Waldbott, G. L.: Emergency Treatment in Asthma (Asthmatic Crisis), J. A. M. A. 110: 1423-1427, 1938.
4. (a) Bases, L., and Kurtin, A.: Prevention of Death in Status Asthmaticus, Value of Bronchoscopy, Arch. Otolaryng. 35: 47, 1942.
   (b) Clerf, L. H.: Progress in Bronchology, J. A. M. A. 136: 733-736, 1948.
5. Prickman, L. E., and Moench, M. S.: Bronchostenosis Complicating Allergic and Infectious Asthma, Ann. Int. Med. 14: 387-392, 1940.
6. Mahone, G. S.: Reaction Following Bronchography With Iodized Oil, J. A. M. A. 130: 194-196, 1946.
7. (a) Waldbott, G. L.: Pathologic Changes in Asthmatic Infants, Am. J. Dis. Child. 49: 1531-1539, 1935.
   (b) Waldbott, G. L.: Allergic Bronchitis, J. Lab. & Clin. Med. 13: 943, 1928.
8. Waldbott, G. L.: So-Called Thymic Death. V. Respiratory Sensitization to General and Local Anesthetics, Arch. Otolaryng. 17: 549, 1933.

BULLOUS EMPHYSEMA

CASE REPORT

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IN THE entire field of chest diseases, there is no diagnostic entity within which there is more confusion than the group of pathologic states variously placed under the heading of "Pulmonary Emphysema." On a few points, however, there is some agreement, viz.:

1. Large air cysts seen in children are generally looked upon as congenital.
2. The development of bullous emphysema is, necessarily, preceded by the loss, quantitative or qualitative (or both), of the elastic tissue of the lung.
3. Once bullous emphysema has developed, the pathologic change is permanent and irreversible.

The reason for this continued confusion is, no doubt, that bullous emphysema is nearly always seen in its end stages and the etiology, origin, and development can be only deduced or surmised.

Early diagnosis, based upon signs or symptoms, is impossible and can occur only as an accidental finding when radiography is used routinely or for the study of some coexisting or underlying condition. The writer believes that cases discovered in this way should be reported because of the valuable light which they may throw upon this morbid state. Such a case is presented below, in which etiology, origin, development, symptomatology, and disappearance are all recorded. This patient has also been observed for a period of ten years (from age 2 to age 12 years) which provides the necessary time interval to test the stability of the restored lung under normal living conditions. There has been no recurrence.

The clinical story, in this case, is factual. It is contrary to many existing beliefs. The purpose of this paper, however, is not to discuss or reconcile divergent opinions, but to let the record speak for itself.

CASE REPORT

W. B. was a white male infant, 2 years old. Two months prior to admission to hospital, the patient developed chicken pox, followed by measles. The measles was complicated by pneumonia and empyema on the left side. For one week prior to admission, he had suffered from violent fits of coughing, accompanied by dyspnea, due to the large amounts of mucopurulent material in the bronchial tree. On admission to hospital on March 27, 1938, the temperature was 103.2° F., pulse 160, respirations 48. The patient was in distress, with moderate cyanosis. On physical examination, there were dullness and absence of breath sounds over the entire left side and râles were present in the right upper lobe both anterior and posterior. There was a purulent discharge from the right ear. The red blood cells numbered 4,080,000; white blood cells, 24,000 with a predominance of poly-

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morphonuclears. Other findings were noncontributory. An x-ray film of the chest (Fig. 1) showed a massive empyema on the left side with displacement of the heart to the right and an area of consolidation in the right upper lobe. On the day following admission, 100 c.c. of straw-colored liquid were removed from the left pleural cavity, from which hemolytic streptococcus was obtained on culture. Aspirations were repeated on several occasions and one performed on April 5 yielded greenish pus. The patient was given general supportive treatment, including transfusions. He continued to be dyspneic, however, and to cough violently, expectorating purulent material similar to that obtained from the pleural cavity. On April 21, the second x-ray film of the chest was made (Fig. 2). This

Fig. 1.

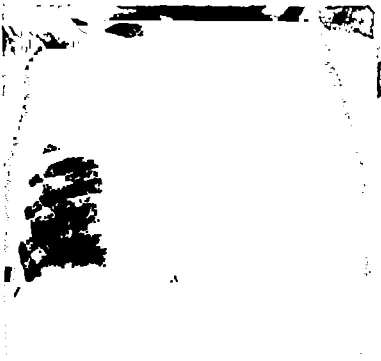
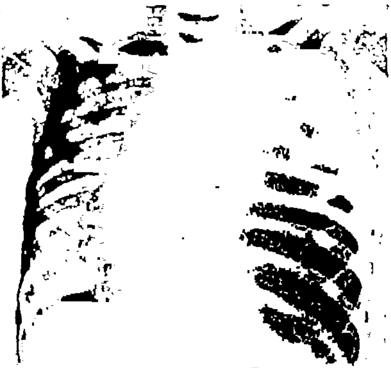
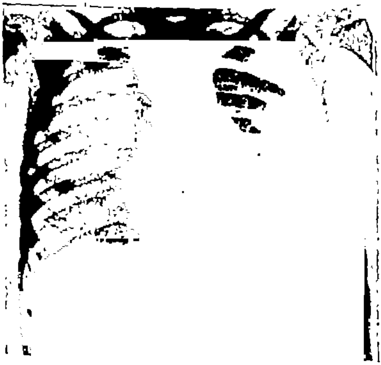


Fig. 2.





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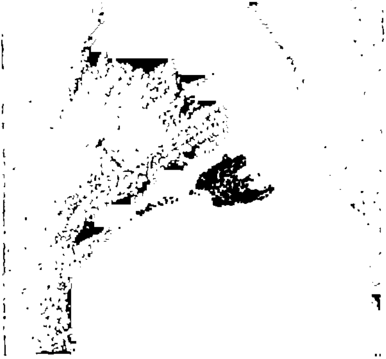


Fig. 4.

Fig. 1.—Posteroanterior view of the chest taken on March 28, 1938, showing massive effusion on the left and an area of consolidation in the right upper lobe.

Fig. 2.—Posteroanterior view of the chest taken on April 21, 1938, showing tension pyopneumothorax left, resolution of the previously consolidated area in the right upper, with high light over its central portion.

Fig. 3.—Posteroanterior view of the chest taken on May 12, 1938, showing partial re-expansion of the left lung. The high light shown in Fig. 2 is now a definite air sac extending down to the fourth anterior rib.

Fig. 4.—Lateral view of the chest taken on June 15, 1938. The circular outline of the air cyst is clearly seen. A fluid level of the residual empyema is also visible in the posterior costal gutter.

demonstrated a tension pyopneumothorax on the left, total atelectasis of the left lung, displacement of the mediastinum to the right and an irregular high light in the area previously showing a consolidation on the right side.

I first saw this patient in consultation on April 27, at which time a diagnosis of bronchopleural fistula with check-valve mechanism on the left side was made and immediate drainage of the empyema was recommended. A thoracotomy with intercostal catheter drainage was performed on April 29 by the surgeon on service. There was some

Fig. 5.

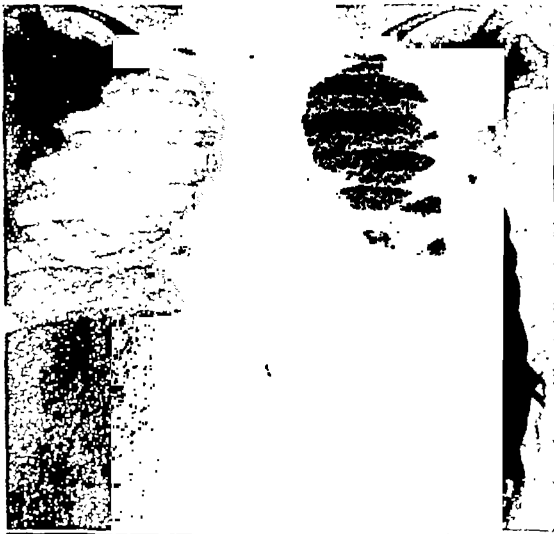
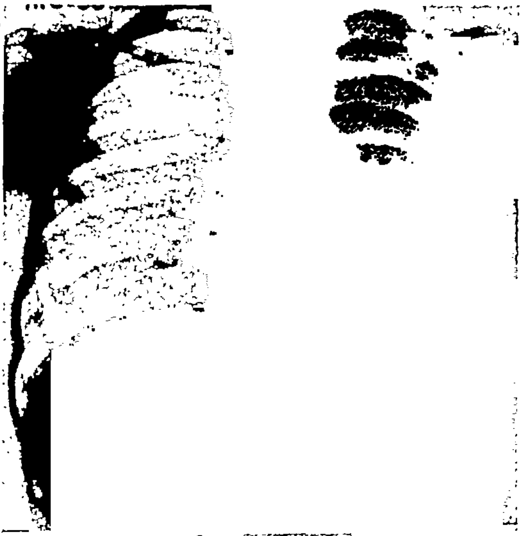


Fig. 6.



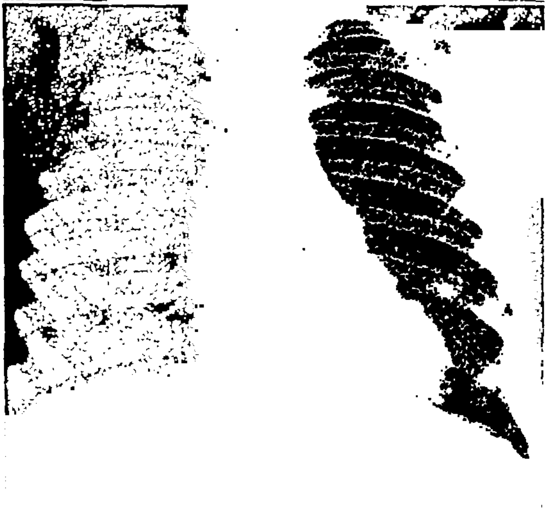


Fig. 7.

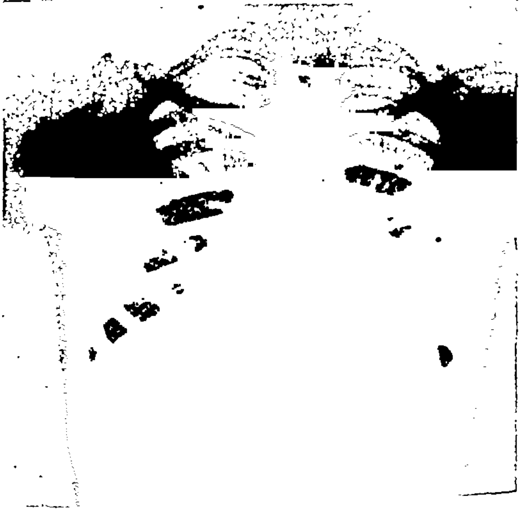


Fig. 8.

Fig. 5.—Posteroanterior view of the chest taken on June 22, 1938. In this exposure, the air cyst has reached its maximum size from apex to fifth anterior rib, with the entire right lung crowded down upon the diaphragm.

Fig. 6.—Posteroanterior exposure of the chest made on Sept. 2, 1938. The disappearance of cough has been followed by resorption of air in the sac and partial return of the right lung to normal.

Fig. 7.—Posteroanterior view of the chest taken on Nov. 25, 1939. All evidence of the previously existing emphysema has disappeared. Note normal markings in the upper lung field right.

Fig. 8.—Posteroanterior view of the chest taken on June 2, 1948, ten years after recovery. Although the patient has had some "colds" since that time, there is no evidence of emphysema in the right lung. Again, normal lung markings are clearly seen over the right upper chest.

relief following this procedure, but drainage proved inadequate and the patient suffered a return of dyspnea and violent fits of coughing and expectoration. The drainage tube required reinsertion on two or three occasions. A third x-ray film (Fig. 3), taken on May 12, demonstrated a residual empyema on the left with partial re-expansion of the left lung, shifting of the mediastinum to its normal position and a large air sac in the upper part of the right lung. A second thoracotomy was then performed by the surgeon who had taken over service on May 1, with the insertion of a larger catheter in the sixth intercostal space, mid-axillary line. Again, temporary relief was afforded, but cough of considerable severity, with the expectoration of purulent material, continued and, by the beginning of June, dyspnea had again developed. A lateral view of the chest (Fig. 4), dated June 15, shows a clear outline of the developing air cyst on the right with a fluid level on the left posterior costal gutter. The patient was transferred to my care on June 16. The drainage site was changed to the eighth intercostal space in the scapular line, with water seal hook-up. Fig. 5, a roentgenogram of the chest taken on June 22, showed a considerable enlargement in the air sac on the right in spite of a satisfactory diminution in the severity of the cough.

From this point onward, the patient made uniform progress toward recovery. He was discharged and referred to the outpatient department for follow-up on Aug. 3, 1938. A check-up x-ray film (Fig. 6) was taken on Sept. 2, 1938, after injection of Lipiodol into the residual sinus. The air cyst in this examination was reduced to about one-third of its previous volume. The patient was kept under observation and a follow-up x-ray picture of the chest was taken on Jan. 25, 1939 (Fig. 7), which showed complete re-expansion of the left lung and complete resorption of the air in the cystic formation on the right side.

A recent roentgenogram (Fig. 8) taken on June 2, 1948, ten years after the first illness, demonstrated a chest of normal appearance. Particularly notable is the distribution of lung markings in the right apical region over the original site of the air cyst.

SUMMARY AND CONCLUSIONS

A case of bullous emphysema of the right lung is reported, in which etiology, development, clinical course, disappearance, and ten-year follow-up are all recorded.

Observations in this case are at variance with many of the accepted opinions on the disease. A study of the facts presented should, therefore, be of value.

REFERENCES

1. Peirce, C. B., and Dirkse, P. R.: Pulmonary Pneumatocele: Certain Considerations in Cystic Disease of the Lung, Radiology 28: 651, 1937.
2. Lereboullet, P., Lelong, M., and Bernard, J.: Image kystique pulmonaire à évolution régressive chez un nourrisson de quatre mois, Bull. Soc. de pédiat. de Paris 34: 77, 1936.

EXPERIMENTAL OBSERVATIONS ON EMBOLISM OF PULMONARY LOBAR ARTERIES

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BECAUSE of the clinical importance of pulmonary embolism, experimental study of obstruction of the pulmonary arterial system has received wide attention. Many of these studies have been concerned particularly with altered cardiorespiratory dynamics and sudden death. Such observations have been extensively reviewed in the past.[1-4]

It is self-evident that simple external compression of the pulmonary arterial circuit may produce critical circulatory block. Haggart and Walker[5] and others[6] have shown that reduction of 60 per cent or more of the pulmonary arterial circulation (by arterial compression) produced a rise of pulmonary arterial blood pressure and a critical decrease in blood flow through the lungs. It is evident also that internal obstruction of the pulmonary arteries, by thrombotic or foreign body emboli, may cause marked impedence of pulmonary flow, and death.[1, 2, 7] On the other hand, some workers have postulated that intense cardiopulmonary reflexes are invoked by lung embolism, and that sudden circulatory failure may result from general arterial constriction ("spasm") of the pulmonary vascular bed.[4, 9, 10] The postulate is based upon evidence that embolic occlusion may cause a sharp rise in pulmonary arterial tension, a fall in cardiac output, bradycardia, dyspnea, and tachypnea, with marked distention of the right cardiac ventricle and engorgement of the systemic veins. Furthermore, these phenomena have occurred with large or small embolic bodies to the lungs.[4] Some evidence has been presented[4, 11] to suggest that pulmonary vascular spasm occurs with very minute embolization of the "capillary" or "precapillary" pulmonary bed. Unfortunately, many of the earlier studies entailed the release of foreign bodies from a peripheral vein permitting random embolization of the lungs. From the descriptions of such experiments it is frequently difficult to judge whether the circulatory and respiratory effects resulted from mechanical vascular block or from "reflexes" involving pulmonary vascular spasm and peripheral vasodepressor responses.

A step toward more adequate control of effects produced by larger lung emboli is found in the work of Hall and Ettinger.[12] Using dogs, they noted that occlusion of the large pulmonary arteries by balloons, or other objects, produced no notable cardiodynamic effects. Furthermore, electrical or mechanical stimulation of the intimal surfaces of these vessels were likewise without significant effect. Their studies indicate that reflex mechanisms are not produced from emboli lodged in the large pulmonary arteries.

Because of the importance of studying the effects of embolization of the secondary, tertiary, and finer arteries of the pulmonary system the following groups of experiments were performed.

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METHOD

Dogs of 10 to 15 kilograms in weight were anesthetized with sodium pentobarbital. The thoraces were opened by a transverse incision entailing removal of the third rib, and positive pressure respiration was applied. Systemic blood pressure was recorded by canalizing a common carotid artery using an optical or mercury manometer. Pulmonary arterial tension was conveniently measured by canalizing a branch of the right upper lobar pulmonary artery and using a manometer of choice. All of the animals were heparinized. Under these conditions, the pulmonary arterial blood pressure ranged between 25 and 15 mm. Hg systolic, and 10 and 5 diastolic. The pressure figures are somewhat lower than those frequently recorded in dogs with closed thoraces,[13, 14] but they are within the limits of normal.

The following procedures were undertaken to study the effects of large emboli to the lungs:

1. Balloons made of one-quarter inch Penrose drain were attached to the ends of No. 8 French urethral catheters, using a specially devised balloon attachment. The device was inserted through a puncture incision in the anterior wall of the main pulmonary artery, and the balloon was pushed to a lobar artery of choice in either lung. The catheter was secured by a purse-string suture to prevent leakage. Inflation of the balloon could then be carried out to any given pressure using a conventional mercury manometer.

In order to embolize secondary arterial branches more distally than could be reached with the balloons, ordinary dried pea seeds were introduced singly into the pulmonary arteries through an incision in the right atrial appendage and were permitted to embolize the pulmonary arterial branches at random. A sufficient number of seeds were introduced, one at a time, to produce elevation of pulmonary pressure. The experiment was terminated at any given time.

In addition, "long emboli" were utilized to occlude and distend a secondary vessel more nearly over its entire length. Four navy beans were threaded together by piercing them with a darning needle and thread, providing an embolus which was flexible and 3 to 4 cm. in length. The bean string could be conveniently introduced through a right atrial incision, and could be guided by digital pressure into the right or left pulmonary branches and thence into a secondary vessel. Position of the string was verified by autopsy after dispatch of the animals.

2. Distention, *without occlusion,* of secondary pulmonary arteries was accomplished by use of an instrument similar to that of Hall and Ettinger[12] and of Megibow and associates.[2] Our instrument (see Fig. 1) was of small size and of sufficient flexibility to be easily inserted into a lobar artery. Insertion of the device was through a puncture in the anterior wall of the main pulmonary artery utilizing the technique for the introduction of the catheter-balloon instrument.

3. Obstruction of the finer distal branches of the pulmonary arteries, using small foreign bodies, was accomplished by insertion of a No. 8 French urethral catheter into a lobar vessel. Foreign bodies of glass beads (1 mm. in diameter) and poppy seeds (0.5 mm. in diameter) were placed in the open ends of the

catheters; these bodies were washed into the artery by small draughts of physiologic saline solution until the lobar artery was firmly impacted.

The occurrence of marked, generalized pulmonary vascular constriction[3, 4, 10, 11] from small emboli is thought to be reflected in a sharp rise of pulmonary arterial tension, a fall of systemic blood pressure, with dyspnea, tachypnea,[9] and bradycardia. These physiologic responses were regarded as the important criteria in these experiments. Accordingly, the carotid arterial and pulmonary arterial pressures and heart rate were frequently recorded. In these open-chest preparations, respiratory effort could not be accurately evaluated, although it was possible to note movements of the thoracic wall during severe dyspnea.

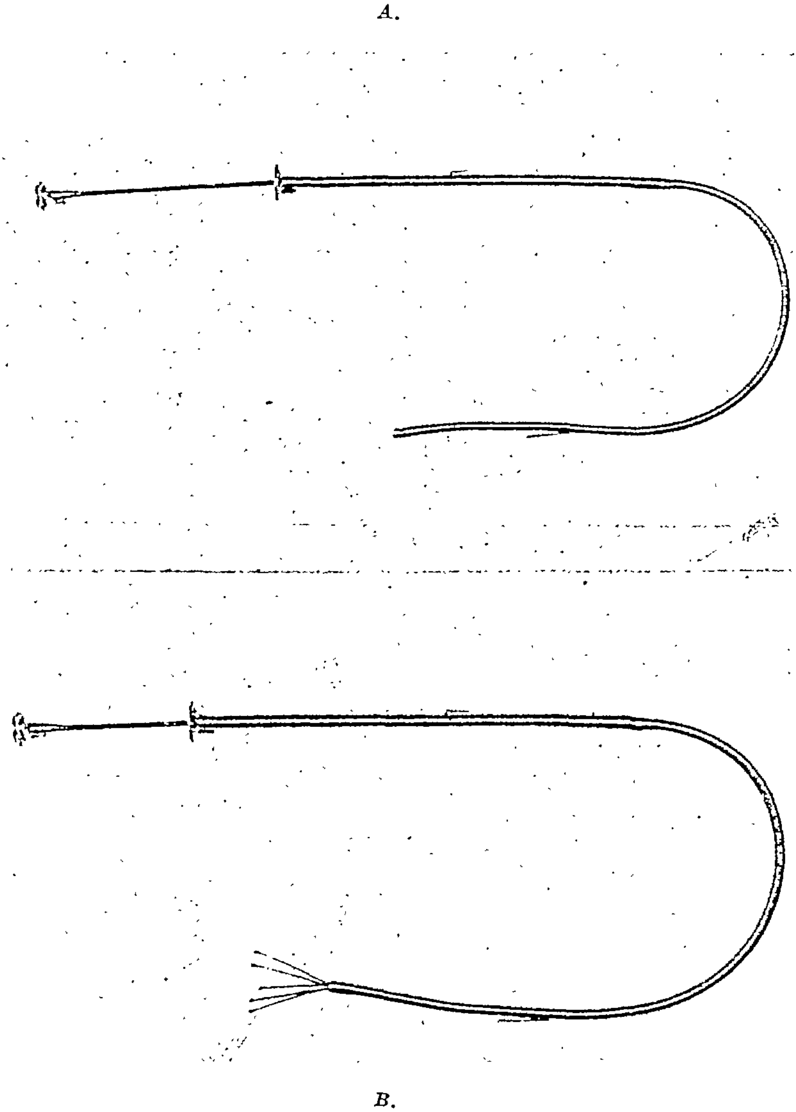

Fig. 1.—Photographs of the spreading instrument: *A*, Showing spreading prongs retracted; *B*, with prongs released. The instrument, made from a camera cable release, is flexible, permitting introduction into pulmonary artery directly, and easy maneuverability to lobar arteries of choice. Flexible cable is 33 cm. long; diameter 3 mm.; the fine spring steel prongs are 23 mm. in length, having a small knob at each tip to prevent tearing of intima and piercing of vessel wall.

RESULTS

Effect of Occlusion and Distention of the Lobar Pulmonary Arteries.—With the catheter and uninflated balloon placed in a lobar artery, no changes in heart rate nor pulmonary and systemic arterial pressures occurred. Subsequent inflation of the balloon likewise produced no changes in cardiovascular dynamics, and no evident respiratory effort. These negative effects upon the dynamics of the circulation persisted with inflating pressures as high as 150 to 300 mm. Hg. It was notable that with inflation of the balloons to 50 mm. Hg or more, the vessel wall, containing the sac, could be seen to be markedly distended. However, if the inflated balloon was placed in either the left or right main pulmonary artery, eliminating the circulation to one lung, a transient rise of pulmonary arterial tension (mean rise of 10 mm. Hg) and a decrease in systemic blood pressure (mean fall of 20 mm. Hg) occurred. The previous pressure levels were restored in three to eight minutes and further circulatory changes were not noted with continued internal occlusion of a main artery. These findings were consistent in nine experiments performed on nine animals.

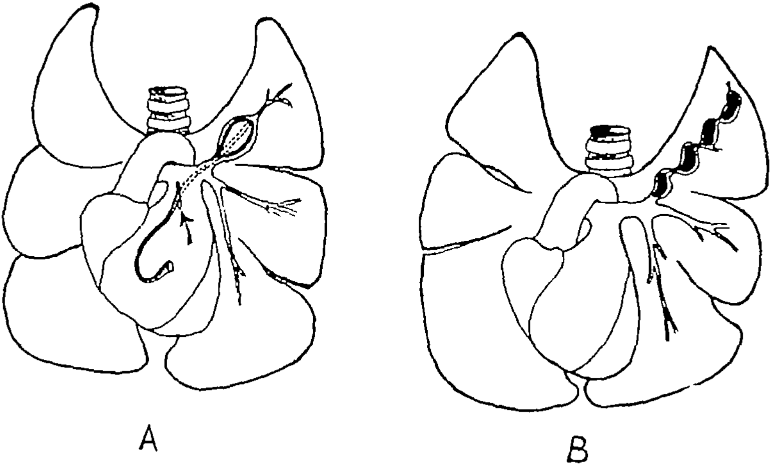

FIG. 2.—*Sketches of the approximate positions of foreign bodies used as emboli.* *A* shows catheter with balloon occupying left middle lobe artery. The distended balloon causes marked distention of the vessel wall. Point of incision of the main pulmonary artery through which the device is inserted is marked by the heavy arrow. *B* shows position of string of four beans occluding and distending a pulmonary lobar artery. In neither case were cardiovascular dynamics altered by these foreign bodies (see text).

The results of embolism of lobar arteries with single or multiple pea seed emboli were confirmatory of the findings of other investigators.[1, 8, 12, 16, 17] In five experiments performed on five dogs, single occlusion of a lobar vessel by one seed produced no cardiocirculatory changes. Such a lack of response might be anticipated from the similar lack of response with introduction *and inflation* of a balloon. Similarly, the introduction of four or five additional pea seeds provoked no cardiovascular responses. However, it was invariably found that, when the positions of the pea emboli were determined by palpation the seeds had passed to only two or three of the lobar arteries and that each of embolized arteries contained one or more of the seeds. Therefore, critical mechanical block of the pulmonary arterial system did not occur and blood flowed freely to the remaining lung lobes. No changes in cardiocirculatory function were noted. Furthermore, embolization of a lobar artery with the flexible bean strings affected no demonstrable changes in cardiovascular performance although the vessel was occluded and distended over much of its length. The latter was noted in five experiments.

Distention and Mechanical Intimal Stimulation of Pulmonary Lobar Arteries.—In four experiments on four dogs, passage of the instrument for distending the lobar arterial walls provoked no circulatory or respiratory effects. Release of the spreading prongs caused marked visible distention of the vessel walls; however, no changes in tension in the greater or lesser circulations, nor in heart rate, were observed. Furthermore the spreading instrument was manipulated longitudinally through various of the arteries to provide sharp mechanical irritation of the intimal surface. This procedure likewise evoked no alterations in circulatory dynamics.

Embolization of Smaller Vessels of the Pulmonary Arterial System With Solid Foreign Bodies.—Since occlusion and distention by emboli of the main and lobar arteries did not produce appreciable effect upon circulatory dynamics, the bead and poppy seed emboli to smaller vessels of the lungs were next utilized.

In a series of five experiments on five animals, the glass beads (1 mm. in diameter), seventy to eighty in number, were introduced into the catheter, twenty or thirty at a time, and propelled into the catheter and artery by small quantities of saline solution. As the beads were being instilled, no measurable effects on the greater or lesser circulations were detected. Following the procedure, palpation of the lobar artery indicated that the beads were firmly impacted in the vessel. Up to one hour following implantation of the beads, no significant changes in systemic or pulmonary circulatory function occurred.

In a similar group of five experiments, the same procedure was utilized with poppy seeds (Ca. 0.5 mm. in diameter) as the embolizing substance. These seeds were instilled to fill an entire lobar artery. Obstruction with these emboli evoked no changes in circulatory performance, the blood pressures and heart rate remaining unaltered. The lobar vessel of choice was distended and solidly filled with the foreign bodies.

COMMENT

The experimental evidence presented here indicates that neither distention nor occlusion of the main pulmonary arterial vessels, nor of the lobar arteries, provokes recognizable reflex or significant mechanical alterations of cardiovascular dynamics. The results are in general agreement with the findings of others. Haynes and co-workers[11] introduced balloons into the pulmonary arteries of dogs with closed thoraces; inflation of the balloons produced no significant changes of pulmonary or systemic blood pressures, heart rate, nor of electrocardiographic pattern. Mendlowitz[1] could not explain alterations in circulatory dynamics as reflexogenic effects from long flexible emboli of barium-filled rubber tubing. Other investigators[15-18] have also noted that obstruction of the larger pulmonary arteries using various types of foreign body emboli is usually not suddenly fatal unless widespread mechanical block of the pulmonary circulation occurs.

It is further apparent from these experiments that occlusion of twigs of the pulmonary lobar arterial system to the size of approximately ½ mm. diameter produces no significant effects upon cardiovascular mechanisms if the embolization is confined to one lobe and widespread mechanical block thus avoided.

It would stand to reason, therefore, that sudden death or immediate distortion of cardiovascular function may not be likely to occur following emboli to the larger lobar vessel systems unless critical mechanical obstruction is established. However, it has been found[1, 2] that death in experimental animals may occur several hours after a large pulmonary embolism has been sustained. Under these conditions the mechanism of death is not clear. Megibow, Katz, and Steinitz[2] suggested that thrombi may be generated by large emboli which are then propogated or disseminated to other parts of the lung arterial system. The evidence advanced by Haynes and associates,[11] suggesting that capillary or precapillary embolization may cause violent acute reflex cardiodynamic effects, raises the possibility that following obstruction of large arteries, the finest vessels become occluded, possibly by miliary fragmentation of thrombi originating from such major pulmonary emboli.

SUMMARY

A study is presented concerning experimental pulmonary embolism, using emboli of various size and shape to the secondary and smaller branches of the pulmonary arterial system. It was found that obstruction of lobar arteries themselves and of the finer lobar vessel twigs (to 0.5 mm. in diameter) produce no immediate significant changes in cardiocirculatory dynamics. It was further demonstrated that mechanical irritation of the lobar vessels, and extreme distention of these vessels without occluding them, likewise had no immediate effect upon the circulatory mechanisms. The conclusion seems justified that major pulmonary embolism does not produce acute cardiopulmonary effects if critical mechanical obstruction of the lung circuit is avoided.

REFERENCES

1. Mendlowitz, M.: Experimental Pulmonary Embolism, J. THORACIC SURG. 8: 204, 1938.
2. Megibow, R. S., Katz, L. N., and Steinitz, F. S.: Dynamic Changes in Experimental Pulmonary Embolism, Surgery 11: 19, 1942.
3. DeTakats, G., Beck, W. C., and Fenn, G. K.: Pulmonary Embolism. An Experimental Study, Surgery 6: 339, 1939.
4. Violet, M.: Recherches expérimentales sur l'embolie pulmonaire mortelle, Presse méd. 47: 682, 1939.
5. Haggart, G. E., and Walker, A. M.: The Physiology of Pulmonary Embolism as Disclosed by Quantitative Occlusion of the Pulmonary Artery, Arch. Surg. 6: 764, 1923.
6. Gibbon, J. H., Jr., and Churchill, E. D.: The Physiology of Massive Pulmonary Embolism. An Experimental Study of the Changes Produced by Obstruction to the Flow of Blood Through the Pulmonary Artery and Its Lobar Branches, Ann. Surg. 104: 811, 1936.
7. Fontaine, R., and Kukovec, R.: Contribution expérimentale à l'étude de l'embolie pulmonaire mortelle, J. de chir. 56: 65, 1940.

8. Singh, I.: Certain Effects of Pulmonary Gas Embolism, J. Physiol. 87: 11, 1936.
9. Megibow, R. S., Katz, L. N., and Feinstein, M.: Kinetics of Respiration in Experimental Pulmonary Embolism, Arch. Int. Med. 71: 536, 1943.
10. Villaret, M., Justin-Besançon, L., and Bardin, P.: Les embodies pulmonaires expérimentales. Étude technique et premiers résultats physiologiques, Ann. de méd. 37: 305, 1935.
11. Haynes, F. W., Kinney, T. D., Hellems, H. K., and Dexter, L.: Circulatory Changes in Experimental Pulmonary Embolism, Federation Proc. 6: 125, 1947.
12. Hall, G. E., and Ettinger, G. H.: An Experimental Study of Pulmonary Embolism, Canad. M. A. J. 28: 357, 1933.
13. Czebrinski, E. W., Smith, J. R., Nemec, S. S., and Robb, J. A.: Measurement of Pulmonary Arterial Pressure in Dogs, J. Lab. & Clin. Med. 30: 849, 1945.
14. Johnson, V., Hamilton, W. F., Katz, L. N., and Weinstein, W.: Studies on the Dynamics of the Pulmonary Circulation, Am. J. Physiol. 120: 624, 1937.
15. Karsner, H. T., and Ghoreyeb, A. A.: Studies in Infarction. III, The Circulation in Experimental Pulmonary Embolism, J. Exper. Med. 18: 507, 1913.
16. Mann, F. C.: Pulmonary Embolism, An Experimental Study, J. Exper. Med. 26: 387, 1917.
17. Mathes, M. E., Holmes, E., and Reichert, F. L.: A Study of Bronchial, Pulmonary, and Lymphatic Circulations of the Lung Under Various Pathological Conditions Experimentally Produced, J. THORACIC SURG. 1: 339, 1932.
18. Binger, C. A. L., Brow, G. R., and Branch, A.: Experimental Studies on Rapid Breathing. II, Tachypnea, Dependent Upon Anoxemia, Resulting From Multiple Emboli in the Larger Branches of the Pulmonary Artery, J. Clin. Investigation 1: 155, 1924.

A SCALE FOR RAPID MEASUREMENT OF BLOOD WHICH IS LOST IN SURGICAL SPONGES

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IN EXTENSIVE operations where blood loss is great, it is possible to keep many patients in a safe condition by viewing the amount of blood lost in the field, keeping count of the pulse and blood pressure, and replacing blood in amounts which appear to keep the individual on a reasonably satisfactory plane. While such haphazard methods are sufficient in most instances, it is widely recognized that fatalities or serious complications can result when replacement therapy is inadequately guided. If too much blood is infused the cardiovascular apparatus may be embarrassed or the heart may fail; if too little blood is given, the patient may develop serious or even fatal shock. Visual impressions of the amount of blood which is lost in an operative field may be quite inaccurate, and the excellent studies of Buddington and Taylor,[1] Miller, Gibbon, and Allbritten,[2] and Wangensteen[3] have shown by accurate measurements that the loss from a patient is often much greater than had been expected. It is not practical to conduct accurate studies of hemoglobin loss during all cases of major surgery. However, when blood loss is high it is desirable to have some rough method for guiding the intravenous infusions. For this purpose, Dr. Alexander H. Bill, Jr., and I have reconstructed a scale on which it is possible to weigh sponges after they have been discarded from the field and to determine rapidly the amount of blood which they contain.

In the operative field only dry sponges are employed; these are of a standard, commercial variety which uniformly weigh 8 Gm. Pads are likewise inserted dry; they uniformly weigh 40 Gm. (the equivalent of five sponges). Since the sponges and the pads have uniform size, it is unnecessary to weigh them before they enter the surgical kit. Using sponges of uniform size makes it possible to employ a weighing scale which is fitted with a rapidly adjustable device which can quickly compensate for the number of sponges which are being weighed. Turning this adjustment will allow the scale pointer to indicate directly the number of grams (or cubic centimeters) of blood contained in the soiled sponges.

The scale (Fig. 1) has been remodeled from an ordinary dietetic scale.* It has a dial face which can be turned. The outer rim (1 cm. wide) of this dial has been marked off at intervals of each 8 Gm. (the weight of dry sponges); these markings are made in a counterclockwise direction. The body of the instrument is fitted with a plate carrying the legend "number of sponges" and a central arrow which lies above the rim of the turnable dial face. The platform of the scale has firmly attached to it a pan which will receive the sponges.

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*Manufactured by the Hanson Scale Company of Chicago.

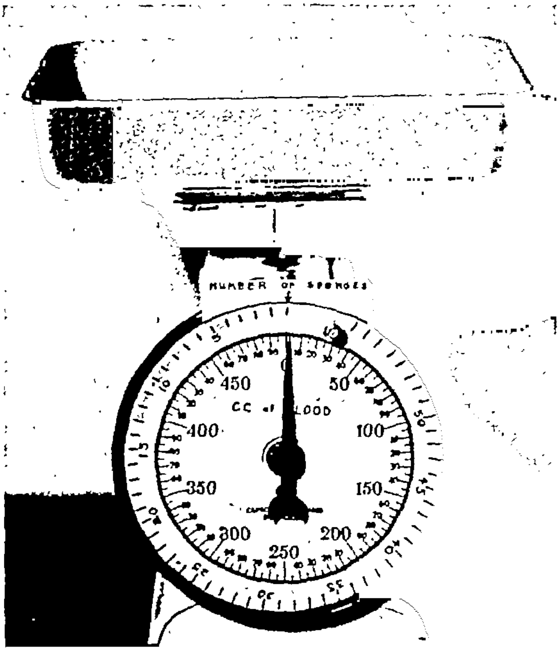

Fig. 1.—Scale for weighing sponges which contain blood. The entire face dial can be rotated around the shaft of the central, main pointer.

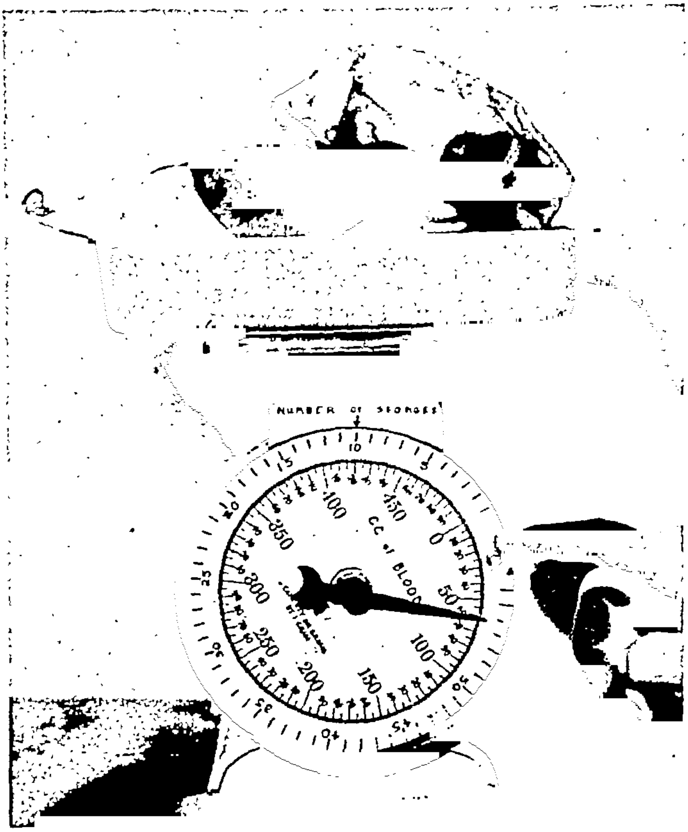

Fig. 2.—The weighing scale in use. Ten blood-soaked sponges have been put in the pan for weighing. With a finger, the face dial is rotated so the figure ten comes opposite to the arrow at the top. The main, central pointer directly indicates that the sponges contain 62 c.c. of blood. (Turning the face dial automatically discounts the weight of ten dry sponges.)

During an operation it is the duty of the circulating nurse occasionally to remove the discarded sponges from the floor bucket and weigh them on the scale which is kept on a side table. If, for instance, ten sponges have been placed in the scale pan (Fig. 2), she simply turns the face dial so that the rim number comes to "10" opposite the arrow at the top of the instrument. *The pointer hand of the instrument will then directly show (on the inner row of numbers of the face dial) the cubic centimeters of blood in the sponges.* These maneuvers take but a few minutes, they require no figuring on the part of the nurse, and they can be carried out in conjunction with her manifold other duties.

It has been my practice to have the circulating nurse keep a rough balance sheet. Each time a load of sponges is weighed, the weight of the blood is added onto the record sheet. To determine the patient's total blood loss at any given moment, it is possible to glance at the bottom figure on this sheet and mentally add to it the amount of blood which resides in the suction-apparatus bottle on the floor. Amounts of blood which are given intravenously are also noted in an appropriate column on the record sheet. This system accomplishes two purposes: First, it allows the circulating nurse to know how much is being lost so that she can replace blood in proper amounts without having to receive instructions from the surgeon or anesthetist who may be having his own difficulties at some particularly critical moment. Second, it permits the surgeon to call at any time for an accounting of the blood balance; he can be told instantly how much has been lost and how much has been replaced. The general method obviously has inaccuracies and it does not account for blood which resides on the drapes, blood which is removed in an excised organ such as a lung, etc. But for practical purposes it is accurate enough; the measured loss indicates the *minimum* amount of blood which must be replaced. As a rule somewhat larger amounts are administered, depending upon the size of the patient, the length of the operation, etc.

This weighing scale was designed for use during operations on coarctation of the aorta. Blood loss from the aorta itself is usually nil or inconsequential, but there may be an astounding leakage from the transected chest wall which has an extremely rich collateral bed in most cases. Large subjects can lose 1,000 to 2,000 c.c. of blood, and in rare instances the figure may be higher. Under such circumstances it is essential to have some simple and rapid method to guide the replacement therapy and keep it within safe limits. For this purpose the scale herein described serves admirably. The implement obviously has uses in other fields of surgery where blood loss is apt to be high and where the use of dry sponges is not objectionable.

REFERENCES

1. Buddington, W. T., and Taylor, G. W.: Loss of Blood in Certain Standard Operations for Malignant Disease, New England J. Med. 218: 285-287, 1938.
2. Miller, B. J., Gibbon, J. H., Jr., and Allbritten, F. F., Jr.: Blood Volume and Extracellular Fluid Changes During Thoracic Operations, J. THORACIC SURG. (In press.)
3. Wangensteen, O. H.: The Controlled Administration of Fluid to Surgical Patients Including Description of Gravimetric Methods of Determining Status of Hydration and Blood Loss During Operation, Minnesota Med. 25: 783-789, 1942.

RELATIVE EFFECTIVENESS OF PARENTERAL, INTRATRACHEAL, AND AEROSOL PENICILLIN IN CHRONIC SUPPURATIVE DISEASE OF THE LUNG

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DIRECT medication of the lung has been practiced for many centuries. With the advent of effective parenteral and oral medication, interest in this type of therapy declined. It was only when certain specific diseases of the lung failed to respond that interest in intratracheal and aerosol therapy was revived. As early as 1920, Winternitz and Smith,[1] in their book on the pathology of war-gas poisoning, demonstrated the inadequacy of general intravascular therapy in the management of lung damage following chlorine and phosgene inhalation, for parenteral therapy did not reach the necrotic, and thereby devascularized, pulmonary epithelium. In asthmatics, the epinephrine-fast state observed with parenteral therapy was frequently overcome by the use of aerosolized preparations of that drug. It was, however, not until the introduction of chemotherapeutic and biotherapeutic agents that aerosol therapy began to assume greater importance in the clinician's armamentarium.

In spite of the widespread use and acceptance of aerosol therapy, several of the basic principles have not been investigated or have been only briefly discussed in the literature. The pharmacodynamics of absorption from the normal lung was reported in a previous study.[2] Penicillin in saline solution was administered to normal male volunteers. One hundred thousand units of crystalline penicillin G potassium were given parenterally, intratracheally, and by aerosol. It was shown that, although the penicillin molecule is readily absorbed into the blood stream from the alveoli, this absorption was notably slower than that following parenteral administration. Blood levels following intratracheal administration did not reach the early high peaks regularly seen with intramuscular injection, but therapeutically significant blood levels were maintained for twice as long a period of time. The more prolonged retention of penicillin within the body following intratracheal injection was further confirmed by the lower urinary excretion. It was shown that aerosolized penicillin solution resulted in blood levels nearly as high as those obtained by intratracheal administration, but persisted for only one-third as long. From comparison of the total urinary excretions of these two methods, it was possible to calculate the efficiency of the areosol method. Approximately 35 per cent of the aerosolized solution was shown to be absorbed by the pulmonary epithelium.

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In a related study,[3] the effect of various other diluents, as compared to saline, was reported. Neosynephrin and epinephrine, bronchovasoconstrictors, caused higher initial blood levels and the therapeutic range compared favorably with saline as diluent. No irritation of the bronchial tree was encountered and there appears to be no contraindication to such diluents for penicillin when their actions on the bronchial tree are indicated. Triethylene glycol and chlorophyll were found to be irritating despite topical anesthesia and no enhancement of penicillin activity was noted. These diluents do not appear to be indicated for intratracheal administration but aerosolized chlorophyll may have a beneficial effect as a diluent for penicillin in the presence of mixed gram-positive and gram-negative infection. Human serum did not alter the absorption pattern and iodized oils as vehicles for penicillin powder were discussed.

The relative effectiveness of many types of apparatus used to produce aerosols is difficult to evaluate. In another study of this series,[4] a critical evaluation of eleven of the most common types of aerosol apparatus was made. The highest and most consistently sustained blood levels were obtained when the Vaponefrin nebulizer was modified to include rebreathing with humidification. Methods for the management of the unconscious patient were described, and it was shown that satisfactory blood levels and urinary excretions can be obtained in such a patient.

The pharmacodynamics of absorption from the lung, the influence of various diluents other than saline, and the best apparatus for the administration of such solutions by inhalation were thus established. It then remained to investigate the effect, if any, which pathologic conditions of the lung may have on fluid exchange from alveoli into the blood stream and vice versa. It is not possible in normal volunteers to establish how much of parenterally administered penicillin reaches the lung. Only in the presence of sputum is material available for evaluating the amount of active agent which reaches the site of pathology. Furthermore, since blood flow is reported to be decreased to portions of lung which are diseased, data concerning the value of parenteral penicillin obtained in normal subjects would not be applicable where abnormal conditions are present.

Volhard introduced the intratracheal tube to medical therapeutics and Meltzer and Auer[5] first made extensive use of it not only for intratracheal insufflation of gases but also for introduction of various solid and liquid substances into the bronchi. As early as 1894, Ribbert[6] described the deficient blood supply of the late inflammatory lesions of the lung. The demonstration of the ineffectiveness of intravascular therapy, because of impaired circulation in the late pneumonic lung, contrasted sharply with the dense impregnation of exudate in such lung by dye injected intrabronchially.[7] Direct medication of this organ was thus suggested as an efficient therapeutic route. World War I interrupted these studies, but in 1920 interest again centered on intratracheal administration for the treatment of war-gas poisoning. Winternitz and Smith[1] studied the effects of pulmonary irrigation and intratracheal medication in the treatment of such poisoning. They demonstrated the relative rapidity with which physiologic salt solution was absorbed from lungs of normal dogs after intratracheal insufflation. Small quantities, such as 30 to 50 c.c., disappeared within forty-eight to seventy-two hours. Administration of phenolsulfonphthalein by various routes demonstrated an appreciably lower rate of absorption (two-hour recovery) following intrapulmonary administration (51.1 per cent) than obtained after intramuscular (72.5 per cent) or intravenous (78 per cent) injection.

Acute inflammatory disorders, such as pneumonia, acute bronchitis, or acute lung abscess, ceased to be major therapeutic problems with the discovery of chemotherapeutic agents. The failure of chronic, purulent, nontuberculous disorders of the lung to respond to parenteral administration of these agents was observed relatively early. Interest in aerosol and, to a lesser extent, intratracheal therapy was, therefore, stimulated. The wealth of clinical evidence for successful aerosol management of various suppurative disorders of the lung quickly and firmly entrenched this mode of therapy in the management of such diseases.[8, 9, 10]

Intratracheal therapy has also been described, but no critical, clinical evaluation has been made. There have been relatively few laboratory demonstrations of the efficacy of such direct medication to the lungs. White and associates,[11] in their extensive study on the prevention of postoperative empyema following lung resection, demonstrated complete absence of penicillin in the bronchial secretions of two patients who received prolonged intramuscular therapy. Bobrowitz and co-workers[12] assayed several samples of sputum following intramuscular administration and could demonstrate only slight penicillin activity in one sputum on only one occasion.

Intratracheal therapy has not had extensive clinical use. Endoscopic insufflation of powdered sulfonamides achieved relatively good results as compared to parenteral therapy when used alone.[13, 14] It appeared, however, that the chief benefit obtained was the reduction of granulation tissue and consequent reduced bleeding tendency. The instillation of liquid sulfonamides has been attempted but found to be large ineffective because of inactivation by para-aminobenzoic acid present in the pus. May and Floyer[15] were the first to describe the treatment of bronchiectasis with intratracheal instillation of penicillin. Under Decicain transcricoid topical anesthesia, 10,000 units of penicillin in 5 to 8 c.c. of water were injected through the cricoid cartilage. Twelve hours later, 10 to 100 units of penicillin per c.c. of sputum were demonstrated. Penicillin activity was detectable in the sputum up to twenty-four hours. Kay and Mead[16] used this type of treatment by the indirect laryngoscopic method without topical anesthesia in ninety-three cases of chronic infections of the lung and bronchi. With a laryngeal cannula, they injected 250 to 50,000 units of penicillin during deep inspiration; patients noted a taste of penicillin for several hours. Ulcerative tracheobronchitis and minimal bronchiectasis responded very well. Moore and Thompson[17] used intrabronchial instillations of penicillin and sulfonamide solution in conjunction with bronchial lavage with great benefit in a case of severe bronchiectasis. Bobrowitz and associates[12] clinically compared intratracheal, aerosol, and intramuscular penicillin in twelve patients with bronchiectasis. They noted maximum benefit in four to six days after intratracheal administration of 100,000 to 150,000 units of penicillin in 10 to 20 c.c. of saline twice a day with topical anesthesia. Several weeks were required before maximum benefit was noted with the aerosol and intramuscular route. The dosage aerosolized was inadequate, however. After intratracheal administration, high blood levels, a 30 per cent total urinary excretion, and considerable penicillin in the sputum were noted. Penicillin was further demonstrated in the sputum for eight days and in the urine for three days. Using only one-fourth to one-sixth as much penicillin daily by the aerosol route, they were nevertheless able to recover 13 units per c.c. from the sputum and 1.8 units per c.c. from the urine; only traces of penicillin were detectable in the blood in two cases and none at all in three cases. On the basis of these low blood concentrations they concluded that not all aerosolized penicillin entered the lungs. Alarcon[18] obtained dramatic results in the treatment of lung abscess by bronchoscopic and direct tracheal instillation of penicillin. Topical use of penicillin solutions has also been found beneficial in the treatment of tracheotomy wounds, the postlaryngectomy state and acute laryngotracheobronchitis.[19] Administration under fluoroscopic control of penicillin suspended in heavy iodized oil has been suggested for the treatment of abscess cavities.[20] It appeared to us that repeated injection of a heavy oil in suppurative conditions of the lung is undesirable. We have used a very thin, easily absorbed oil (Pantopaque) in similar fashion.[3]

It is, therefore, clear that parenteral therapy alone is unsatisfactory in the chronic suppurative diseases of the lung. The failure of such chemo- and biotherapeutic agents may lie in their inability to reach the site of the lesion.

Having demonstrated the mode of absorption of penicillin from the normal lung,[2, 3] there now remain to be studied: (1) the effect which the chronically diseased lung exerts on this absorption mechanism, and (2) the penicillin concentration in diseased portions of the lung following various methods of administration. Patients with profuse purulent sputum were therefore selected and were given the same amount of penicillin intramuscularly, endotracheally, and by aerosol. The urinary and sputum excretion of penicillin as well as the blood-level curves were then compared.

METHODS

Patients selected had a confirmed diagnosis of some chronic purulent disorder of the lung and raised a large daily volume of sputum. These studies do not represent an attempt at treatment or at clinical evaluation of the results of these individual administrations of penicillin. Routine therapy was resumed after this short period of study. Penicillin was administered intratracheally through a No. 14 French urethral catheter following thorough anesthesia of the tracheobronchial tree with a dilute solution of Pontocaine. The details of this procedure as carried out by us are described elsewhere.[2] This was well tolerated in all instances and no untoward reactions due to the Pontocaine anesthesia were encountered. Unlike the normal volunteers of previous studies,[2, 3] these patients were encouraged to cough as soon as possible after the topical anesthesia had worn off. Cough and expectoration were usually resumed about one-half hour after instillation. Blood was collected at one-half and one hour after administration and every hour thereafter for six to ten hours. Specimens of urine and sputum were collected one, two, four, six, and twenty-four hours after administration of the penicillin. Sputum and urine were kept on ice during and after the period of collection. The routine was exactly the same when the intramuscular route was employed. For aerosolization the Vaponefrin nebulizer and an attached rubber rebreathing bag with humidification were used. Blood samples were collected for four hours; sputum and urine specimens were collected at the same time intervals following endotracheal administration. Penicillin assays were made by the Rammelkamp dilution method,[21] the limitations and modifications of which we have previously discussed.[2]

CASE HISTORIES AND RESULTS

CASE 1.—T. M., a 59-year-old white laborer, was admitted to the Sixth Medical Service, complaining of an almost uninterrupted productive cough for the past thirty years following a "bronchial catarrh." The sputum, most profuse in the early morning, was described as greenish yellow and occasionally foul smelling. Nine months ago, he first noted some shortness of breath and one week ago he began to feel feverish, experienced mild chills, and noted a dull, steady pain in the right chest, radiating to the back. For the past three days he had suffered from severe headache and "catching" pain in the left chest, worse on coughing and on deep inspiration.

Past history revealed a previous admission to this hospital nine months before for lobar pneumonia, right middle and lower lobe, pneumococcus type 8, and chronic alcoholism with delirium tremens. The patient denied any other episodes of pneumonia or influenza, there were no recent weight loss, night sweats, or hemoptysis, and no family history of, or contact with, tuberculosis. Excessive alcohol consumption for many years was admitted.

Physical examination revealed an elderly, well-nourished, well-developed white man in no acute distress. Temperature on admission was 99.6° F., blood pressure was 120 systolic and 70 diastolic, the pulse rate was 100 per minute and respiratory rate was 22 per minute. There were bilateral immature cataracts, complete anodontia, and marked injection of the pharynx. Examination of the chest showed prolonged expirations and sonorous râles throughout both lung fields. A friction rub was felt in the left axilla. Physical examination was otherwise within normal limits.

Course.—Laboratory examination of the blood, urine, stool, and spinal fluid was normal, as were venous pressure, circulation time, and blood and spinal fluid serology. The sedimentation rate was elevated. The electrocardiogram showed left axis deviation. The patient produced 400 to 800 c.c. of thick green sputum a day. Bacteriologic examination revealed alpha and beta hemolytic streptococci, *Neisseria flava,* and *Micrococcus catarrhalis.* Anaerobic culture did not contribute further. Repeated sputum concentrates were negative for acid-fast bacilli.

Therapy consisted of intensive postural drainage, full doses of parenteral penicillin and aerosol therapy of 50,000 units of penicillin dissolved in 1 c.c. of 0.25 per cent Neosynephrin. Bronchoscopy revealed profuse purulent exudate arising principally from the right middle and left lower lobe orifices. Bronchography confirmed the diagnostic impression of bronchiectasis. There were advanced saccular involvement of the left lower and right middle lobes and lesser involvement of the lingular branch of the left upper lobe as well as the right lower lobe. It was felt that the extent of the involvement, as well as the patient's age, precluded surgical treatment.

On the thirty-seventh day, treatment was interrupted and on the thirty-ninth, forty-first, and forty-third days, penicillin absorption studies were done as outlined above. Previous therapy was then reinstituted. The patient became afebrile on the second hospital day and remained so throughout his two-month hospital course. Somewhat improved, he was then discharged to the care of a Veterans' Facility. His cough at the time was still productive of 60 to 120 c.c. of odorless sputum a day.

Results.—(Table I and Fig. 1.) Blood-level curves following intramuscular administration reveal a quickly reached peak of 1.25 units per c.c. of serum followed by a rapid decline. Therapeutically significant levels were maintained for four hours. Following endotracheal

TABLE I. TABULATION OF BLOOD, URINE AND SPUTUM LEVELS OF PENICILLIN FOLLOWING THE ADMINISTRATION OF 100,000 UNITS OF CRYSTALLINE PENICILLIN G POTASSIUM BY VARIOUS ROUTES IN FOUR CASES OF CHRONIC SUPPURATIVE DISEASE OF THE LUNG

	BLOOD UNITS PER C.C. OF SERUM (HOURS AFTER DOSE)							URINE UNITS PER HOUR (HOURS AFTER DOSE)						SPUTUM UNITS PER HOUR (HOURS AFTER DOSE)						
	½	1	2	3	4	5	6	1	2	4	6	24	TOTAL	1	2	3	4	5	6	TOTAL
Intramuscular.—																				
Case 1	1.25	0.625	0.312	0.078	0.039	0	0	18,750	4,750	12,200	–	250	35,950	0	0	0	0	0	–	0
2	0.625	0.312	0.078	0.039	0	0	0	72,500	10,750	4,750	796	900	89,696	0	0	0	0	0	0	0
3	2.5	1.25	0.156	0.078	0	0	0	22,500	6,250	14,750	–	1,875	45,375	0	–	–	0	–	–	0
4	1.25	0.625	0.319	0.078	0.039	0	0	12,000	8,000	9,000	6,500	100	35,600	–	0	0	0	0	0	0
Endotracheal.—																				
Case 1	0.078	0.078	0.078	0.039	0.039	0.019	0	1,250	1,250	3,500	–	600	6,600	12,300	2,090	105	97	180	0	14,772
2	0.156	0.156	0.156	0.156	0.078	0.039	0.078	1,218	4,688	7,650	2,100	3,000	32,986	13,750	8,125	8,750	4,000	35	24	34,684
3	0.078	0.156	0.156	0.156	0.078	0.039	0.019	7,188	2,370	7,125	–	225	14,538	35,000	38,780	9,690	0	0	–	83,470
4	0.312	0.312	0.312	0.156	0.156	0.039	0.019	8,000	1,250	3,313	499	750	13,812	20,280	4,212	4,514	4,212	0	0	33,218
Aerosol.—																				
Case 1	0.039	0.019	0.019	0	0	–	–	1,170	–	–	–	550	1,720	12,500	3,120	190	0	0	–	15,810
2	0.039	0.019	0.019	0	0	–	–	2,808	370	370	67	2,025	5,068	4,836	1,007	0	0	0	0	5,843
3	0.019	0.039	0.039	0	0	–	–	2,184	1,363	–	–	450	4,197	4,056	–	988	0	0	–	5,044
4	0.156	0.078	0.078	0.039	0	0	0	530	1,230	937	–	16	2,733	7,956	9,048	4,290	2,067	1,989	0	25,350

administration, the peak reached was .08 unit per c.c. of serum which was maintained for two hours, the curve was much flatter and therapeutic levels were also maintained for four hours. After aerosol administration, a peak of 0.4 unit was reached after one-half hour, but this significant level was not maintained. Urinary excretions parallel these results. On intramuscular injection, the total excretion was 35 per cent, with a very high peak in the first hour. Only 6.6 per cent was excreted after endotracheal injection and it is interesting to note that more penicillin was excreted during the third and fourth hours than during the first and second hours. The total penicillin excretion, following aerosol administration, was 1.7 per cent.

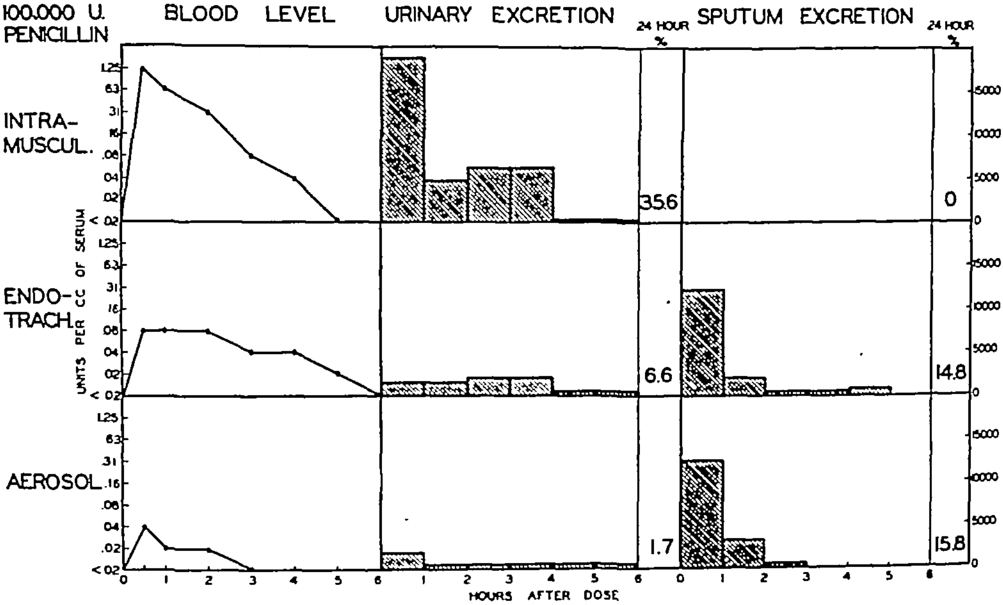

Fig. 1 (Case 1).—Blood levels, urinary excretion, and sputum excretion following the administration of 100,000 units of crystalline penicillin G potassium by various routes. T. M., 59-year-old white man with advanced bronchiectasis.

No trace of penicillin was recovered from the sputum at any time following intramuscular injection. Intratracheal injection gave rise to 12,300 units in the sputum during the first hour and at the end of five hours there were still 180 units. An equal amount, 12,500 units, was expectorated during the first hour following aerosol administration and at the end of three hours there were still 190 units per hour in the sputum. A total of 14.8 per cent was expectorated following endotracheal administration and a total of 15.8 per cent following aerosol administration.

Case 2.—M. R., a 38-year-old Italian salesman was admitted to the Thoracic Surgery Service complaining of chest pain and productive cough. He had been entirely well until one year ago, when he developed what was thought to be pneumonia and was treated at home for several weeks. His cough soon became productive of large quantities of foul sputum. A chest x-ray film at the time revealed a large cavity of the right upper lobe and he was admitted to the Sanatorium Division of the Boston City Hospital. During a three-month observation period all sputum cultures, guinea pig inoculations, and direct smears of concentrates were negative for acid-fast organisms. Follow-up chest plates showed the solitary cavity to be increasing in size, and the quantity of sputum also had increased. A diagnosis of chronic purulent lung abscess was made and the patient was referred to the Thoracic Surgery Service.

Physical examination revealed an emaciated man with an almost continuous profusely productive cough. The only significant findings were those of the right lung which were indicative of a cavity involving almost the entire organ.

Course.—Neither the cough and sputum, nor the low-grade fever were favorably influenced by intensive postural drainage, large doses of parenteral and aerosol penicillin and streptomycin. Bronchoscopy demonstrated much granulation tissue and profuse purulent material in the right main-stem bronchus. Papanicolaou smear of the bronchial aspirations did not show tumor cells and biopsy was negative. In spite of this, it was felt that the most likely diagnosis was excavating bronchiogenic carcinoma. The patient became increasingly ill and lost 25 pounds. After four weeks, he agreed to surgery and a right exploratory thoracotomy was performed. The entire right lung proved to be densely adherent and the hilar structures were enveloped in an inflammatoy mass. The abscess appeared to involve the right upper and middle lobes. Two frozen sections revealed chronic inflammation only, and, in view of the patient's extremely poor physical condition, the thought of pneumonectomy was abandoned in favor of a cavernostomy. The abscessed cavity was packed open and later drained with rubber tubes. Sputum rapidly decreased, he began to gain weight, and was discharged to the Thoracic Out-Patient Clinic. He did relatively well while at home but continued to expectorate moderate quantities of foul sputum. Successive chest plates revealed the right upper lobe to be partly collapsed with a small apical pneumothorax. It was felt, however, that the remaining cavity was too large to close spontaneously and he was readmitted for thoracoplasty.

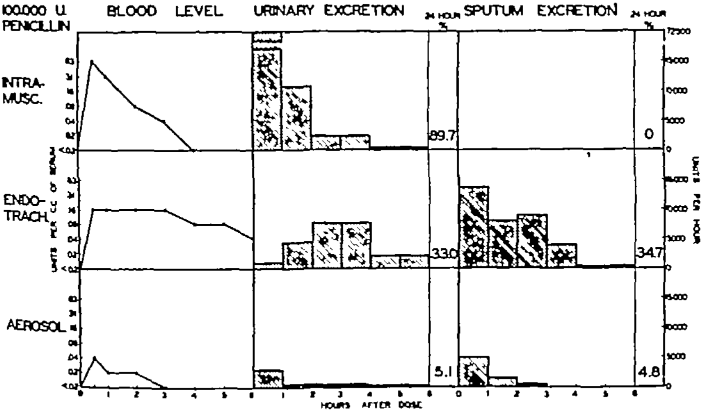

Fig. 2 (Case 2).—Blood levels, urinary excretion, and sputum excretion following the administration of 100,000 units of crystalline penicillin G potassium by various routes. M. R., 38-year-old white man with lung abscess of right middle and upper lobe.

During this admission penicillin studies were done. A four-stage thoracoplasty with partial scapulectomy was performed. During the last stage, the posterior portions of the fifth, sixth, seventh, and eighth ribs were removed and the wound was extended into the chronic empyema cavity overlying the abscess and packed wide open. This wound healed rapidly and the patient was discharged eight months after his first admission, the wound completely closed, the cavity collapsed and free of sputum.

Results.—(Table I and Fig. 2.) The blood-level curve, following intramuscular injection, reached a peak of 0.63 unit per c.c. at one-half hour and thereafter declined rapidly. Significant levels were maintained for three hours. Total urinary excretion was 89.7 per cent with a peak of 72,500 units excreted during the first hour. No trace of penicillin could be detected in any of the sputum samples following intramuscular administration. Endotracheal administration produced a peak of 0.16 unit per c.c. of serum after one-half hour, and this peak was maintained for three hours. Therapeutic levels were still assayed at the end of six hours. Total urinary excretion was 33 per cent. Only 1,248 units of penicillin were excreted during the first hour, while 7,650 units per hour were excreted during the third and fourth hours. During the first hour 13,750 units of penicillin were excreted in the sputum; at the end of six hours there were still 24 units per hour; and at the end of nine hours, 18 units per hour. The patient expectorated a total of 671 c.c. of sputum containing 34,700 units of penicillin during a twenty-four hour period. Following aerosol administration, a significant blood level was observed at the end of one-half hour. The total urinary excretion was 5.1 per cent and 4.8 per cent was expectorated, 4,836 units during the first hour, and there were still 1,007 units during the third hour.

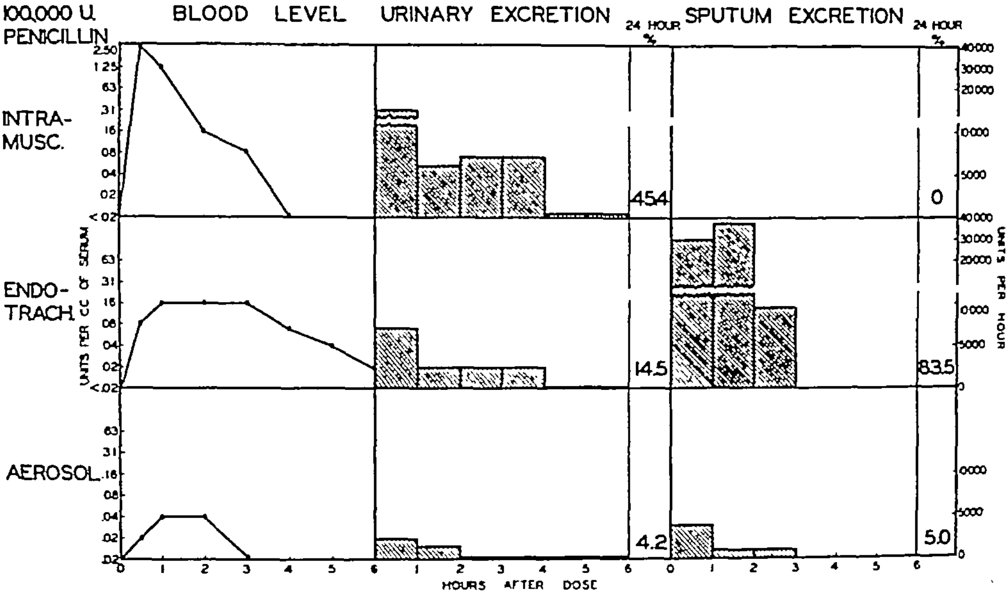

Fig. 3 (Case 3).—Blood levels, urinary excretion, and sputum excretion following the administration of 100,000 units of crystalline penicillin G potassium by various routes. T. M., 17-year-old white girl with bilateral bronchiectasis and tuberculosis.

Case 3.—T. M., a 17-year-old white girl student was admitted to the Thoracic Surgery Service for the sixth time complaining of a chronic productive cough. She was first admitted six years before and treated for right lower lobe pneumonia. She was readmitted three years later because of a cough of three months' duration. At the time, a diagnosis of bronchiectasis of both lower lobes was confirmed by bronchography. Two years ago bronchography revealed severe bronchiectasis of the right middle and lower lobes and minimal involvement of the left lower lobe and lingula. It was felt, at the time, that the patient would be greatly improved though probably not cured by a resection and, consequently, a right middle and lower lobe lobectomy was performed. Convalescence was uneventful and she was discharged greatly improved. She was entirely well for about six weeks while at home and then, following a cold, again developed severe cough and copious sputum. Large quantities of secretions removed from both main stems at bronchoscopy, and x-ray examination at the time, revealed a small shadow at the right apex, and the possibility of tuberculosis was considered. Sputum concentrates, smears, cultures, and guinea pig inoculations in the past and at this admission were negative. The patient was discharged improved following a course of intramuscular and aerosol penicillin. Further bronchograms confirmed bronchiectatic involvement of the left lower lobe and lingula. The present admission again was for productive cough following a cold and sore throat. She also complained of weakness and exertional dyspnea. One day before entry she noted, for the first time, some blood-streaked sputum.

Physical examination revealed a young chronically ill girl. The pharynx and nose were injected, and râles and wheezes at both lung bases were heard. Except for a small mass measuring 1 by 3 cm. in diameter in the upper outer quadrant of the right breast and a thoracotomy scar, physical examination was otherwise negative. Our studies were carried out and she was then placed on a regular regime of aerosol and intramuscular penicillin on which she improved very rapidly. Bronchograms again demonstrated marked bronchiectasis of the left lower lobe and lingula and slight involvement of the dependent branches of the remaining right upper lobe. Of the first eight sputum concentrates for acid-fast organisms, two were reported positive. Several guinea pig inoculations of sputum were negative but one of several gastric aspirations showed tuberculous infection at the end of six weeks. On strict bed rest and intermittent penicillin therapy, the patient gained 30 pounds and improved greatly. Sputum was reduced to 1 ounce a day. Results of pulmonary function studies and differential bronchospirometry, as well as extent of involvement, precluded further surgery and the patient is awaiting admission to a sanatorium.

Results.—(Table I and Fig. 3.) Following intramuscular injection, blood serum levels reached a peak of 2.5 units of penicillin per c.c. of serum and the levels then quickly fell off, therapeutically significant amounts being detectable at the end of three hours. Urinary excretion was 45.4 per cent with a peak of 22,500 units during the first hour. No trace of penicillin was detected at any time in the sputum following intramuscular administration. After endotracheal administration, the blood levels did not reach a peak until the end of one hour and were then maintained at this level of 0.16 unit per c.c. for three hours. Significant activity was still present at the end of five hours and penicillin was detectable in the blood at the end of six hours. There was excretion of 14.5 per cent of the administered dose in the urine and 83.5 per cent in the sputum, 35,000 units during the first hour, 38,780 units during the second hour, and 9,690 units during the third hour. Following aerosol administration, a peak of 0.04 unit per c.c. was reached at the end of one hour and maintained for one hour. The total urinary excretion was 4.2 per cent and 5 per cent of the total amount administered was expectorated. At the end of three hours, 988 units were still present in the sputum.

CASE 4.—S. G., a 48-year-old, white, single window washer entered the Fifth Medical Service complaining of hoarseness and a cough of six weeks' duration. He stated that he was entirely well until six weeks before admission when he began to notice a rather severe cough, more noticeable at night, at first productive of moderate quantities of white sputum and later of large quantities of thick greenish sputum. He became increasingly fatigued and lost 10 pounds. He denied having had recent contact with tuberculosis, and having night sweats, chills and fever There had never been any frank hemoptysis or blood streaking of the sputum. Shortly before entry, his cough became severe enough to prevent sleep.

His mother died of tuberculosis and one brother of dropsy. The patient's health had always been good except for one episode one year ago characterized by weakness and swelling of both legs; this led to his first admission at this hospital. Discharge diagnosis was chronic Bright's disease with renal edema and cirrhosis of the liver. He left the hospital before further evaluation was possible. Shortly after leaving, the edema disappeared and he felt entirely well until the present episode. He admitted alcoholic intake of 10 to 12 glasses of beer and 1 quart of whiskey every day for the past ten to fifteen years.

Physical examination revealed a well-developed, well-nourished white man in no acute distress. The blood pressure was 130 systolic and 90 diastolic, the temperature was 101° F., the pulse 80 per minute, and respirations 30. Many teeth were absent and the remaining ones were in extremely poor condition. His gums appeared to be infected, and the pharynx was injected. Speech was extremely hoarse; the vocal cords were swollen and edematous but moved equally. Examination of the lungs revealed normal tactile and vocal fremitus and no dullness to percussion but some expiratory wheezes throughout both lung fields with fine crackling râles over the left chest posteriorly. There was some tenderness in the right upper quadrant and the liver edge was found to be 1 cm. below the costal margin by percussion but could not be palpated. Clubbing of both upper extremities was the only other physical finding.

Course.—X-ray examination of the chest demonstrated an area of decreased density, with fluid level, at the base of the right upper lobe posteriorly, consistent with lung abscess. Examination of the urine revealed 1+ albumin and two to four red cells per high-power field. Examination of blood elements and chemistry was normal. Sputum concentrates were examined for acid-fast organisms and the sediment was injected into two guinea pigs. The sputum was also cultured for acid-fast organisms. All of these examinations proved to be negative. Culture of the sputum revealed alpha and beta hemolytic streptococci, *micrococcus catarrhalis, Neisseria flava, Staphylococcus albus,* and diphtheroids. Anaerobic culture of the sputum did not further contribute. Two blood cultures were negative. Bronchoscopy performed on the twelfth hospital day revealed thick, purulent, grossly blood secretions coming from the right upper lobe orifice, which was completely occluded by tumor and/or granulation tissue. A biopsy taken from this region revealed squamous metaplasia. Papanicolaou smears for tumor cells were negative. The diagnostic impression was putrid abscess of the posterolateral segment of the right upper lobe with possible carcinomatous degeneration, and the patient was transferred to the Thoracic Surgery Service.

Penicillin therapy, instituted on admission, was then interrupted for our usual studies at the inhalation laboratory. Intensive penicillin aerosol and parenteral threapy as well as postural drainage was continued and two further bronchoscopies demonstrated improvement of the local lesion. A biopsy of a right anterior cervical lymph node proved to be negative for metastatic carcinoma. A chest x-ray film on the thirty-ninth hospital day revealed considerable improvement. The abscess had dimnished to almost half its former size and the fluid level had disappeared. There were still occasional temperature rises to about 100° F. On the fortieth hospital day the patient could not tolerate bed rest any longer and left the hospital against the advice of his physicians. Despite appointments and Social Service follow-up, he has never been seen at the clinic.

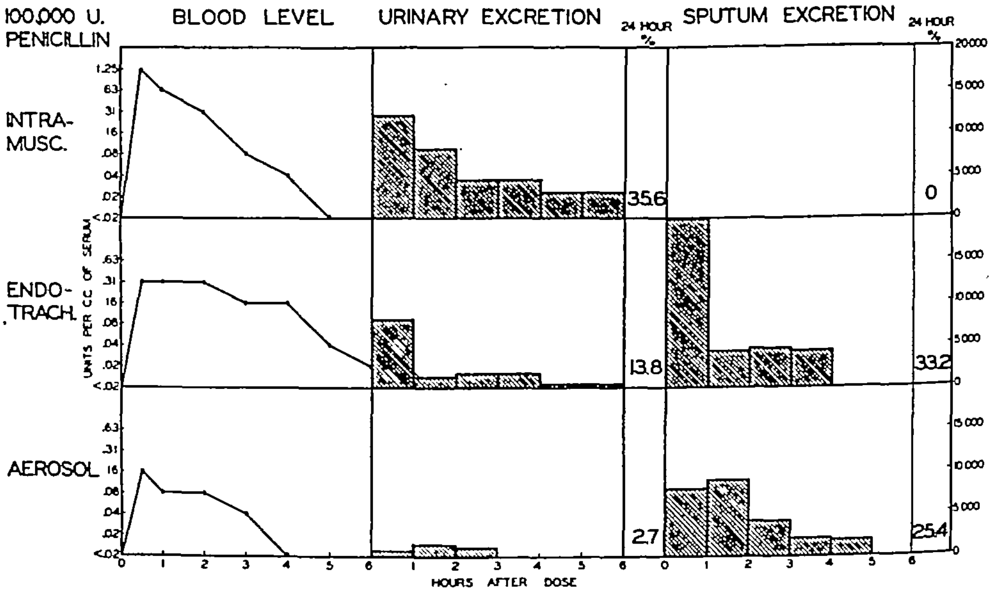

Fig. 4 (Case 4).—Blood levels, urinary excretion, and sputum excretion following the administration of 100,000 units of crystalline penicillin G potassium by various routes. S. G., 48-year-old white man with lung abscess of right upper lobe.

Results.—(Table I and Fig. 4.) Following intramuscular injection, blood levels rose to a peak of 1.25 units per c.c. after one-half hour, significant levels being present for four hours. The total urinary excretion was 35.6 per cent and no penicillin was detected at any time in the sputum following intramuscular administration. A peak of 0.31 unit per c.c. was reached one-half hour after endotracheal administration and this peak was maintained for three hours. Significant levels were maintained for five hours and penicillin was still demonstrable in the blood at the end of six hours. The total urinary excretion was 13.8 per cent and 33.2 per cent of the administered quantity was expectorated with a peak of 20,280 units during the first hour. At the end of four hours, 4,212 units per hour were still expectorated. Following aerosol administration, a peak of 0.16 unit per c.c. was reached at the end of one hour and therapeutic levels were still detected at the end of three hours. The total urinary excretion was 2.7 per cent and 25.4 per cent of the administered dose was expectorated—7,956 units during the first hour, 9,048 units during the second hour, and 1,989 units were still expectorated during the fifth hour.

DISCUSSION

In each of the four patients studied, no penicillin could be detected in the sputum at any time following intramuscular injection of 100,000 units. Following both aerosol and endotracheal administration, significant penicillin activity in the sputum of the same patients was noted for long periods of time. High sputum concentration with the latter routes are to be expected. The inability of intramuscularly administered penicillin to reach the sputum in even the smallest detectable amounts was very striking. These findings are consistent with the clinical impression of the inability of parenteral therapy to cope effectively with chronic purulent disorders of the lung. Roentgenographic and clinical improvement following intravascular therapy in lung abscess and bronchiectasis are probbaly due to resolution of the surrounding pneumonitis rather than to real penetration of the abscess cavities. Direct quantitative measurement of the amount of penicillin which reaches the pulmonary epithelium of the normal or acutely inflamed lung following intramuscular administration is not easily possible. From the successful use of oral and parenteral sulfonamides and penicillin in the acute infectious disorders of the lung, it can be deduced, however, that in the absence of an avascular thickened abscess wall, good concentrations must reach the alveoli. Collection of respiratory-tract fluid from animals by means of a T tube ligated into the trachea[22] has demonstrated as high a concentration of sulfadiazine in this fluid as in the blood for four hours after oral administration. The rigid, thick, avascular wall of the chronic lung cavity must, therefore, represent an efficient barrier to the admission of intravascularly administered penicillin.

From these and other studies, certain conclusions may be made regarding the mechanism of penicillin absorption from the diseased lung. Since parenteral penicillin does not penetrate the purulent cavity, it follows that penicillin should not reach the general circulation from within the cavity. However, the average total urinary excretions in these four patients compare favorably with those obtained following similar administration to normal volunteers.[2] Accurate placement of the penicillin solely at the site of the lesion is not possible. Therefore, the high blood levels and total urinary excretions must be the result of absorption from those portions of the lung that are not diseased. Inasmuch as expectoration was encouraged, a sizeable portion of the administered penicillin was lost in the sputum. Both the blood-level curves and the total urinary excretions are, therefore, somewhat lower with aerosol and intratracheal administration than comparable results obtained with normal lungs.

The demonstrable failure of effectiveness of the parenteral route in the presence of chronic suppuration makes it apparent that direct medication of the lung, either by aerosol or intratracheal instillation, is necessary to alter favorably the pathologic conditions. The endotracheal method, while simple enough, has several disadvantages. Topical anesthesia is usually employed to assure penetration of penicillin into the distal portions of the tracheobronchial tree. Such suppression of the cough reflex as well as the ever-present risk of reaction to such anesthesia are undesirable. Furthermore, irritation and edema of the vocal cords will occur with repeated manipulation with a catheter.

The chief disadvantage inherent in the aerosol method is the wastage that occurs. We have previously shown that 35 per cent of the aerosolized penicillin actually is absorbed from the lung. From the data presented, however, the marked efficiency of either method in placing many hundred times a minimum therapeutic concentration of penicillin at the site of the disease is apparent. Good levels are maintained for about five hours with intratracheal and for three hours after aerosol administration. A repetition of the aerosol therapy rather than intratracheal injections at these respective time intervals appears to be the more practical method. In fact, it is questionable whether too high concentrations of penicillin are necessary or even desirable in the respiratory tract. Proetz[23] has reported that, while concentrations of 500 units per c.c. of penicillin do not impair the ciliary motion of isolated tracheal strips from the rabbit, concentrations of 5,000 units per c.c. reduce the speed of the ciliary motion within three to six hours, long before signs of surface disintegration occur. Furthermore, Eagle[24] has recently shown that with increasing concentrations of penicillin in body fluids bacteriostasis is not correspondingly increased. On the contrary, after certain optimum concentrations, a paradoxical zone appears and bacteriostasis appears to fall off. It seems, therefore, that more than adequate concentrations of penicillin in purulent lung cavities can be maintained with inhalation of 100,000 units, and possibly smaller doses, every three or four hours. Most patients quickly learn how to use the aerosol apparatus and can, if necessary, continue this form of therapy at home. Proper handbulb aerosolization has been shown to give adequate blood levels.[4] The need for intratracheal manipulation with its attendant disadvantages is, therefore, not present. Although an occasional patient may learn to introduce an intratracheal tube himself,[14] the aerosol method, because of its wide applicability and ease of administration, is to be preferred.

Endotracheal administration may present certain advantages. It is not definitely known how deeply aerosolized penicillin actually penetrates purulent cavities. The addition of wetting agents to the solution may increase the depth of penetration. The only force which carries the minute particles of the aerosol into the lung is the respiratory motion. Drinker and Hardenbergh,[25] during a study of dye and protein absorption from the lung, predicted rapid absorption of as small a molecule as that of penicillin. However, they expressed doubt as to how deeply such inhaled mists would penetrate deep suppurative foci with their lost respiratory motion. May and Floyer[15] felt that aerosols might not enter bronchiectatic cavities any better than parenteral penicillin because of deficient aeration of the diseased lung. There appears to be little stimulus for minute aerosol particles to enter such a rigid motionless cavity. It appears entirely possible that a thick-walled hollow cavity, unaffected by respiratory motion, could be reached only by a gravitational flow of penicillin such as that which follows direct injection of fluid. Nevertheless, the striking amelioration of symptoms following aerosol therapy, reported by most observers, strongly suggests some penicillin being effective in the depth of such purulent cavities.

Intratracheal therapy, while certainly an effective means of getting the penicillin to where it is most needed, is not recommended for routine use because of previously described disadvantages. However, under certain conditions, it may be the indicated route of therapy: (1) where endotracheal intubation is necessary for other reasons such as at the time of bronchoscopy or bronchography; (2) in thoracic surgery, during routine postoperative tracheal aspirations, to prevent atelectasis and to promote the cough reflex; and (3) where a rapid improvement of symptoms and reduction of sputum are necessary, as for instance, preoperatively to resection for bronchiectasis or abscess. In the last instance, repeated intratracheal administration is certainly less traumatic but probably less effective than repeated preoperative bronchoscopic aspirations with penicillin injection. In all other instances, aerosolization appears to be the ideal method for the medical treatment of such purulent disorders of the lung.

SUMMARY

1. Four patients with chronic purulent disorders of the lung (bronchiectasis and lung abscess) were studied. Each patient received 100,000 units of penicillin intramuscularly, intratracheally, and by the aerosol route. Blood, urine, and sputum specimens were collected over a twenty-four hour period, following administration, and were assayed for their penicillin content.

2. None of the four patients showed detectable penicillin activity in the sputum at any time following intramuscular injection of 100,000 units of penicillin.

3. The blood levels and urine excretion with the endotracheal and aerosol routes were approximately the same as those found in the normal lung. This may be interpreted as demonstrating systemic absorption from the normal portions of the diseased lung.

4. There was expectoration of 14 to 83 per cent of the penicillin administered during the first six hours following intratracheal administration; 5 to 25 per cent of the penicillin was recovered in the sputum following aerosol administration.

5. Both the intratracheal and aerosol methods were shown to be effective. The latter is generally to be preferred except where intubation is necessary for other reasons. The intratracheal route of administration is further suggested as a rapid means of decreasing sputum and cough prior to surgery.

6. Some form of direct medication of the lung is indicated in the treatment of chronic purulent disorders of the lung.

REFERENCES

1. Winternitz, C. M., and Smith, G. H.: Preliminary Studies on Intratracheal Therapy, Collected Studies on the Pathology of War Gas Poisoning, New Haven, 1920, Yale University Press.
2. Gaensler, E. A., Beakey, J. F., and Segal, M. S.: Pharmacodynamics of Pulmonary Absorption in Man. I. Aerosol and Intratracheal Penicillin, Ann. Int. Med., to be published.
3. Beakey, J. F., Gaensler, E. A., and Segal, M. S.: Pharmacodynamics of Pulmonary Absorption in Man. II. The Influence of Various Diluents on Aerosol and Intratracheal Penicillin. Submitted for Publication, 1948.
4. Beakey, J. F., Gaensler, E. A., and Segal, M. S.: A Comparative Study of Various Apparatus and Technique for Aerosol Administration, Connecticut M. J., to be published.
5. Meltzer, S. J., and Auer, J.: Eine Vergleichung der "Volhardschen Methode der Kuenstlichen Atmung" mit der von Meltzer und Auer in der Kontinuierlichen Respiration ohne Respiratorische Bewegung Verwendete Methode, Zentralbl. f. Physiol. 23: 442, 1909.
6. Ribbert, K.: Ueber die Ursachen der Blutarmuth grau hepatisierter Lungen, Virchows Arch. f. path. Anat. 136: 363, 1894.
7. Kline, B. S., and Winternitz, C. M.: Studies Upon Experimental Pneumonia in Rabbits. VIII. Intra Vitam Staining in Experimental Pneumonia, and the Circulation in the *Pneumonic Lung, J. Exper. Med.* 21: 311-319, 1915.
8. Bryson, V., Sansome, E., and Laskin, S.: Aerosolization of Penicillin Solutions, Science 100: 33-35, 1944.
9. Barach, A. L., Silberstein, F. H., Oppenheimer, E. T., Hunter, T., and Saroka, M.: Inhalation of Penicillin Aerosol in Patients With Bronchial Asthma, Chronic Bronchitis, Bronchiectasis and Lung Abscess. Preliminary Report, Ann. Int. Med. 22: 485, 1945.
10. Segal, M. S., and Ryder, C. M.: Penicillin Aerosolization in the Treatment of Serious Respiratory Infections. A Preliminary Report, New England J. Med. 233: 747, 1945.
11. White, W. L., Burnett, W. E., Bailey, C. P., Rosemond, G. P., Norris, C. W., Favorite, G. O., Spaulding, E. H., Bondi, A., Jr., and Fowler, R. H.: Use of Penicillin in Prevention of Post-operative Empyema Following Lung Resection, J A. M. A. 126: 1016-1024, 1944.
12. Bobrowitz, I. D., Edlin, J. S., Bassin, S., and Wooley, J. S.: Penicillin in the Treatment of Bronchiectasis, New England J. Med. 234: 141-147, 1946.
13. Tucker, G., and Atkins, J. P.: Recent Trends in the Bronchologic Use of Chemotherapeutic and Biotherapeutic Agents, Ann. Otol., Rhin. & Laryng. 53: 777-786, 1944.
14. Vinson, P. P.: Treatment of Chronic Nontuberculous Pulmonary Infection by Bronchoscopy and Insufflation of Sulfonamide Compounds, Ann. Otol., Rhin. & Laryng. 53: 787-790, 1944.
15. May, H. B., and Floyer, M. A.: Infected Bronchiectasis Treated With Intratracheal Penicillin, Brit. M. J. 1: 907, 1945.
16. Kay, E. B., and Meade, R. H., Jr.: Penicillin in the Treatment of Chronic Infections of Lungs and Bronchi; Analysis of 93 Cases, J. A. M. A. 129: 200-204, 1945.
17. Moore, F. H., and Thompson, J. W.: Intrabronchial Instillation of Penicillin or Sulfonamide Solution, With Bronchial Lavage in Treatment of Severe Bronchiectasis, U. S. Nav. M. Bull. 45: 1097-1103, 1945.
18. Alarcon, D. G.: Penicillin in Acute Suppurations of the Lung, Dis. of Chest 13: 211-220, 1947.
19. Andrews, A. H., Jr., and Holinger, P. H.: Penicillin Therapy in the Trachea and Bronchi, Ann. Otol., Rhin. & Laryng. 55: 617-628, 1946.
20. Romansky, M. J., Dugan, D. J., and Rittman, G. E.: Penicillin in Iodized Oil for Instillation into the Lungs, Science 102: 255, 1945.
21. Rammelkamp, C. H.: A Method of Determining the Concentration of Penicillin in Body Fluids and Exudates, Proc. Soc. Exper. Biol. & Med. 51: 95, 1942.
22. Boyd, E. M., and Dorrance, J. A.: The Concentration of Sulphonamide in Bronchial or Respiratory Tract Fluid Following Oral Administration, Rev. canad. de biol. 5: 257, 1946.
23. Proetz, A. W.: Cilia and Penicillin, Ann. Otol., Rhin. & Laryng. 54: 94-95, 1945.
24. Eagle, H.: A Paradoxical Zone Phenomenon in the Bactericidal Action of Penicillin, Science 107: 44-45, 1948.
25. Drinker, C. K., and Hardenbergh, E.: The Absorption of Fluids From the Lungs, J. Exper. Med. 86: 7-18, 1947.

LIPOID GRANULOMA OF THE LUNG FOLLOWING BRONCHOGRAPHY WITH IODIZED OIL

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SICARD and Forestier[1] in 1922 in France, using Lipiodol (Lafay), which is iodized poppy-seed oil, introduced iodized oil as a contrast medium for studying the bronchial tree in human subjects. Since then several other oils, including sesame oil, rapeseed oil, olive oil, and peanut oil, have been halogenated with iodine, an iodine-chlorine combination, or bromine and used in bronchography. As a diagnostic measure bronchography has been widely employed and is generally regarded as a relatively safe procedure. There have been reports of acute reactions, a few of them fatal, after bronchography. These have practically all been attributed to anaphylaxis, iodism, or mechanical overfilling or obstruction of bronchi.

We have recently observed a case in which at operation three weeks after bronchography with Iodochlorol (iodized and chlorinated peanut oil) a granulomatous process was found in the lung, apparently caused by the iodized oil. In reviewing the literature we have been able to find reports of only three similar cases in which histologic study of pulmonary tissue showed a pathologic process apparently caused by the presence in the lung of iodized oil.

In 1934, Rabinovitch and Lederer,[2] writing on lipoid pneumonia, stated that one of them had recently observed a case in which post-mortem study revealed changes in the lung similar to those seen in lipoid pneumonia and apparently caused by iodized poppy-seed oil which had been administered sometime before death. They did not give further details of the case.

Wright,[3] in 1935, reported a case of bronchiogenic carcinoma in which, one year after bronchography with iodized rapeseed oil, the opaque medium could be seen roentgenographically in the lung, where it had apparently been trapped by the presence of the tumor in the bronchus. Post-mortem study of the lung in this region showed the presence of much oil in droplets enclosed in a kind of "cellular syncytium," which had replaced nearly all of the pulmonary tissue in the lobe involved. Wright concluded that the reaction had been caused by the prolonged presence of the iodized oil.

In 1943, Brody[4] described a case of what he termed "focal lipid granulomatosis" discovered at operation one month after bronchography had been done using iodized poppy-seed oil. He found in this case, scattered beneath the pleura and throughout the parenchyma of the involved lobes, numerous firm, ovoid, sharply circumscribed, gray-brown nodules, measuring up to 1 cm. in diameter. Microscopically, the nodules consisted of aggregates of tubercle-like structures, the centers of many of which contained fat globules. Many of the fat globules had foreign-body giant cells stretched around them and the latter

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were surrounded by epithelioid cells and macrophages with a peripheral rim of lymphocytes and fibroblasts. Roentgenograms of thin slices of tissue showed radiopaque regions which agreed in size and distribution with the oil droplets seen in the microsections. In this case also a bronchial tumor partially obstructed the bronchi to the lobes in which the granulomatous reaction occurred.

In the case to be reported the findings were very similar to those in Brody's case, except that there was no obstructing bronchial lesion.

REPORT OF CASE

The patient was a white woman, aged 22 years, who registered at the Mayo Clinic in September, 1947. Her history was quite characteristic of bronchiectasis. There was no history of the use of oily nose drops and bronchography had not been done. Stereoscopic roentgenograms of the chest were reported as showing "very extensive bronchiectasis both bases." Bilateral bronchograms using 20 c.c. of Iodochlorol on both sides were done Sept. 25, 1947. Iodochlorol, as described by the manufacturer, contains "27 per cent iodine and 7.5 per cent chlorine in organic combination with a highly refined peanut oil." It is the medium which has been used in bronchography at the clinic almost exclusively for the past six or seven years without ill effect. The bronchograms in this case showed bronchiectasis involving the left lower lobe but because lingular involvement was uncertain, a left bronchogram using 15 c.c. of Iodochlorol was made four days later. This study showed bronchiectasis in the lingula. The patient was hospitalized on Oct. 2, 1947, for preoperative penicillin therapy. Between October 2 and October 5, temperatures of 99.5° F. were recorded on three occasions but during the remainder of the preoperative period her course was afebrile. On October 10 the patient complained of some itching and an erythematous macular type of eruption was noted on the skin of the anterior surface of the chest and thighs, but this apparently subsided rapidly and its nature is uncertain.

On October 14, left thoracotomy was done. At operation the left lower lobe was found to contain many small yellowish gray nodules, some of which lay just beneath the pleura. A similar large region was noted occupying about a third of the volume of the left upper lobe and located chiefly in the anterior basal portion of the lobe. Biopsy of one of the nodules showed lipoid granuloma on fresh frozen section. Left lower lobectomy and lingulectomy were done. When the remaining portion of the left upper lobe was re-expanded it was noted that the nodular region in that lobe was still present.

After operation the patient required oxygen therapy for four days, becoming dyspneic whenever the oxygen was withdrawn. Except for this, her postoperative course was not unusual. Postoperative roentgenograms of the chest showed a large amount of residual iodized oil in both lungs. These roentgenograms showed no shadow which could be said to represent an infiltration in the lung in the vicinity of the solid region described in the left upper lobe at operation, but there was in this region a rather large collection of iodized oil as can be seen on the roentgenogram taken the day after operation (Fig. 1). The remainder of the patient's course was quite satisfactory. When she returned for clinical study, six months later, on April 27, 1948, she reported that she had felt well, had gained weight, and that, although she coughed occasionally, the cough was no longer productive. A roentgenogram of the chest at this time (Fig. 2) showed good expansion of the remaining left upper lobe and a marked reduction of the amount of iodized oil in the lung.

PATHOLOGY

Grossly, the resected portions of the left lung showed bronchiectasis. In addition, the left lower lobe contained a number of solid, yellowish gray areas sharply demarcated from the surrounding lung tissue (Fig. 3). These ranged from 1 mm. to 1.5 cm. in diameter and were grouped in an area involving about

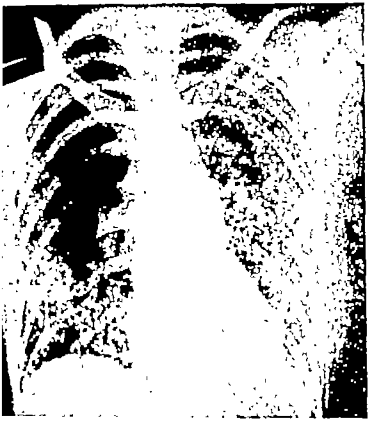


Fig. 1.

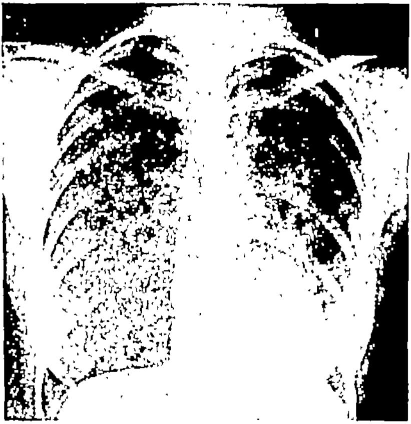


Fig. 2.

Fig. 1.—Roentgenogram of chest taken on day after left lower lobectomy and lingulectomy shows a large amount of residual iodized oil bilaterally. The collection of opaque material in the base of the remaining left upper lobe may represent the solid region described in this lobe at operation.

Fig. 2.—Roentgenogram of chest six months after operation shows good expansion of the remaining left upper lobe and almost complete disappearance of the residual opaque medium seen on the roentgenogram taken immediately after operation.

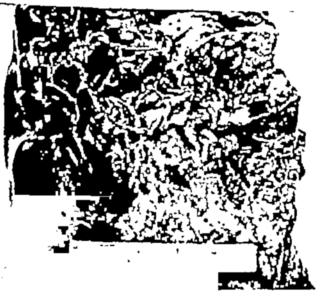


Fig. 3.

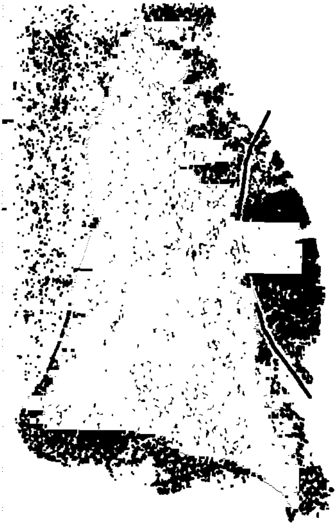


Fig. 4.

Fig. 3.—Photograph of the operative specimen (left lower lobe) shows the solid nature of one of the granulomatous nodules where it has been cut across.

Fig. 4.—Roentgenogram of the specimen of the left lower lobe *shows that the lung in the* solidified region contained a large amount of radiopaque material. The white line represents a wire laid over the specimen to demarcate the region occupied by the nodules as seen grossly.

one-sixth of the left lower lobe in its periphery anteromedially. The larger nodules tended to fuse with one another, forming an irregular region of consolidation with scattered separate nodules around it. A roentgenogram of the specimen showed that the lung in the solidified regions contained a large amount of radiopaque material (Fig. 4). A roentgenogram of a block of tissue from the solid region (Fig. 5) showed the presence of small masses of opaque material, which agreed in size and distribution with small masses of a material which stained orange red with Sudan IV in frozen sections cut from the same block of tissue (Fig. 6).

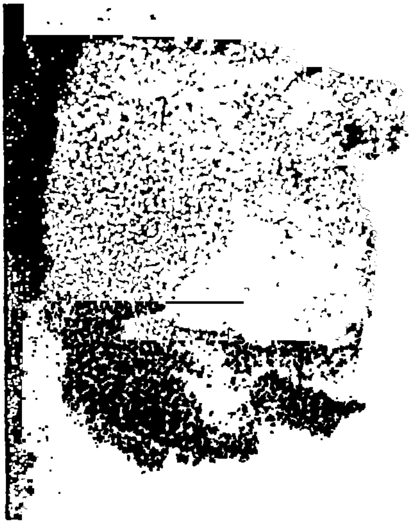


Fig. 5.

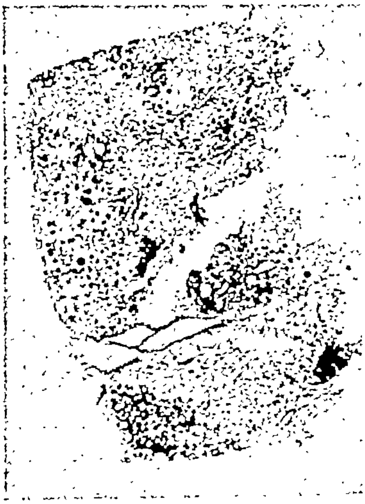


Fig. 6.

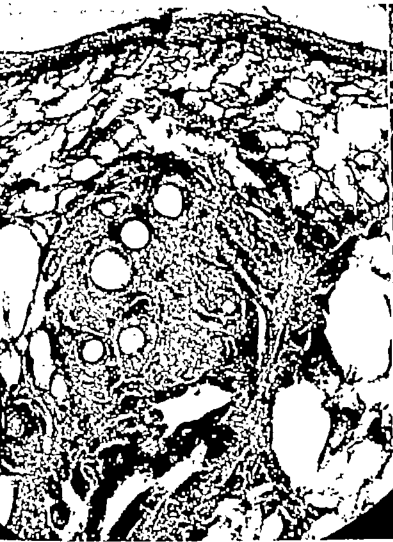
Fig. 5.—Roentgenogram of a block of tissue from a region of granuloma shows distribution of opaque medium in this block.

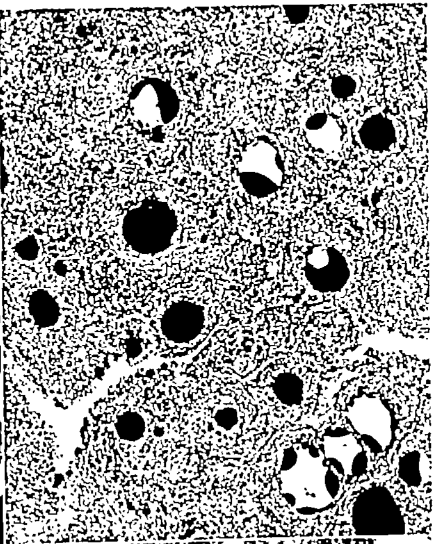
Fig. 6.—Low-power view (×2.7) of a section cut from the block in Fig. 5, stained with Sudan IV, shows small masses of material scattered through the section which appear black in the photograph but were actually bright red.

Microscopic study of tissue from the solid region (Figs. 7 and 8) showed a granulomatous process made up of tubercle-like structures containing various-sized globules of a substance which stained orange red with Sudan IV, blue and crimson with Nile blue sulfate, and black with osmic acid. These staining reactions indicated that the substance in question was an oil. Multinucleated giant cells were found stretched around some of the oil globules. Other oil globules were surrounded by masses of epithelioid cells containing scattered giant cells (Fig. 9). In addition, there were present within the granulomatous tissue regions of definite necrosis in intimate association with masses of oil (Fig. 10). Sections of the surrounding pulmonary tissue which had appeared normal on gross inspection, revealed on microscopic examination a similar but less marked reaction with the presence of mononuclear cells.

Chemical analysis by Dr. M. H. Power showed that tissue from the granulomatous region contained three hundred times as much iodine per gram of wet tissue as did tissue from other regions of the lung which appeared grossly normal.

The gross and microscopic pathologic findings in this case were those of lipoid granuloma. Since the substance found scattered through the granulo-





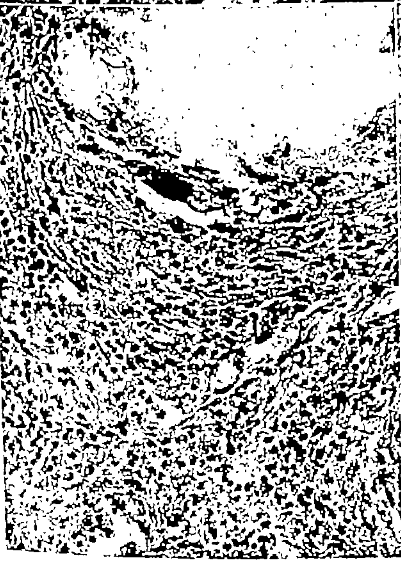


Fig. 9.

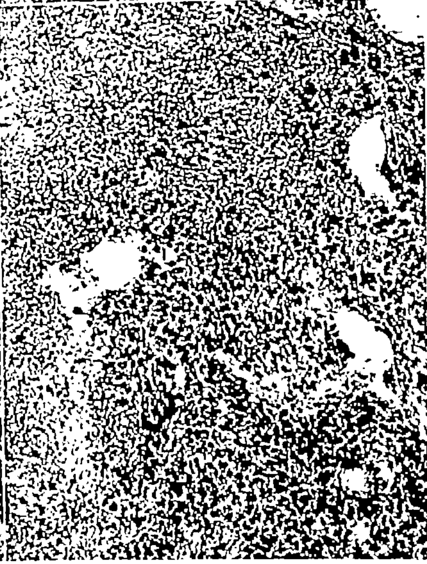


Fig. 10.

Fig. 7.—Low-power view (×26) of one of the smaller nodules stained with hematoxylin and eosin. The nodule is sharply circumscribed from the surrounding lung tissue and has at its center clefts which contained iodized oil. The oil has been dissolved out in tissue processing.

Fig. 8.—Section stained with Sudan IV shows solid region of granuloma containing small masses of oil which stained bright red but which appear black in the photograph (×55).

Fig. 9.—Higher power view (×110) of section stained with hematoxylin and eosin shows epithelioid cells and a giant cell adjacent to a cleft which once contained an oil droplet.

Fig. 10.—Granuloma with an area of necrosis in the upper left-hand corner (hematoxylin and eosin ×90).

matous regions and at the centers of the granulomatous nodules was by staining reaction an oil, by roentgenographic examination an opaque substance, and by chemical analysis of high iodine content, the conclusion that it was the iodized oil used for bronchography seems certain. The relation of the oil globules to the granuloma is such that one must conclude that the granuloma developed in response to the presence of the iodized oil.

COMMENT

The question of what reaction might be caused in the lung by the introduction of iodized oils used in bronchography has stimulated considerable investigation. Ballon and Ballon,[5] in 1927, from a study of 100 cases in which Lipiodol bronchography had been done and from experimental work with cats, concluded that there was no immediate reaction to this substance and no late reaction when it persisted in the lung even for long periods. Fried and Whitaker,[6] in the same year, using iodized poppy-seed oil and iodized sesame oil, studied the histologic change in the lungs of animals at intervals after intratracheal injection. They reported that the reaction to the oil in the lungs was confined to the cells lining the alveolar walls, which, being normally macrophages in a resting state, became transformed into wandering phagocytes and picked up the oil in their cytoplasm. They found regions where these cells proliferated, forming cellular, tumorlike masses which collapsed the alveoli and destroyed the normal architecture of the lungs.

In 1928, Pinkerton[7] made studies of the reaction of the lungs of dogs and rabbits to various oils with particular interest in determining whether the iodized oils used in bronchography were capable of producing reactions similar to those known to have been produced by other oils. He concluded: (1) that most vegetable oils (including iodized poppy-seed oil and iodized sesame oil) produced practically no reaction in the lungs even though retained there for a considerable period; (2) that mineral oil was quickly emulsified in the lungs and taken up by phagocytes which collected in large numbers, filling the alveoli and producing consolidation, which was later followed by fibrosis; (3) that animal oils (such as lard oil and cod liver oil) produced solid yellowish regions in the lung which microscopically showed masses of oil surrounded by a tubercle-like granulomatous reaction made up of giant cells and mononuclear phagocytes with occasional regions of necrosis, particularly when animal oils containing a relatively high percentage of fatty acids had been used; (4) that the reaction of the lungs to an oil varied directly with the free fatty acid content of that oil; and (5) that the simple vegetable oils used in bronchography, since they had a very low content of free fatty acid and apparently were little affected by the lipase activity of the lungs to be broken down to fatty acids, were quite safe for use.

Brown,[8] in 1928, studied the reaction of the lungs of cats to injections of iodized oil and concluded that the presence of the oil in healthy alveoli excited a mononuclear infiltration of the large phagocytic type and that these large phagocytes were the prime factors in the removal of the oil from the alveoli, carrying the oil along the lymphatics to the hilar lymph nodes.

In 1929, Bettman, Kelly, and Crohn,[9] using dogs, reported that most of the iodized poppy-seed oil introduced intratracheally was expelled from the bronchial tree by coughing and that even though small amounts were retained for as long as seven months, the presence of this oil did not cause a definite foreign-body reaction.

Bezançon, Delarue, and Valet-Bellot,[10] in France, in 1935, reported histologic studies of post-mortem material from three cases observed two days, twelve days, and six years after instillation of iodized oil. They concluded that: (1) iodized oil used in bronchography reached the alveoli, where the greater part of it remained free, not causing any histologic reaction and being removed by expectoration; (2) a small part of the oil was rapidly fixed in the alveolar walls by a process of intraparietal phagocytosis, producing a mild interstitial reaction and being gradually broken down by the lipolytic action of the pulmonary parenchyma. They suggested that the long retention of iodized oil occasionally observed on roentgenograms was due to a deficiency of the lipolytic activity of the lungs.

Gowar and Gilmour,[11] in 1941, reported on histologic studies of the lungs of rabbits at intervals after injection of an iodized oil and concluded that the only pathologic change that could definitely be attributed to the iodized oil was the presence of epithelioid cells which formed nodules. They found little evidence of phagocytosis of the oil and no evidence of removal of the oil from the lung by migration of macrophages. Chesterman,[12] in 1942, using essentially the same technique with cats, found that three of eleven animals into which iodized oil had been injected showed sharply circumscribed regions of consolidation which were grossly yellow and which microscopically showed large phagocytic cells containing globules of oil, together with exudation of polymorphonuclear leucocytes and epithelial proliferation.

The pathologic evidence in this case, in our opinion, indicates definitely that the granulomatous process found in the lung at operation was caused by the presence of the iodized peanut oil introduced for the purpose of making bronchograms. The recognition of such a process developing in response to iodized oil must be a very rare occurrence, since so few similar cases have been reported. It seems entirely possible, however, that lesser degrees of such reaction may occur more often than has been recognized. Studies with animals, using various iodized oils, have indicated that there is usually little reaction of the lung to these substances, but investigators have reported finding masses of epithelioid cells which had destroyed the normal pulmonary architecture in some regions. These masses of epithelioid cells were apparently quite small in most instances but could represent a mild degree of the same reaction as was present in this case.

It seems very unlikely that the iodized peanut oil used in this case was any different from that which has been used in hundreds of other cases here and one must conclude that the pulmonary tissue of this patient reacted in a different manner to contact with iodized peanut oil than does the pulmonary tissue of the average person. The reaction found in this lung with formation of granuloma and necrosis was very similar to that which Pinkerton described as occurring in response to animal oils of high fatty acid content. Perhaps this patient's lung possessed a very high degree of the lipase activity, described by several French writers, and rapidly broke down a portion of the peanut oil, releasing irritating fatty acids which caused the necrosis and the formation of granuloma.

The question whether peanut oil might be undesirable as a base for iodized oil has been considered. Boldrey and Aird,[13] in 1944, after experimental studies concluded that iodized peanut oil injected intrathecally was less irritating to the meninges than iodized poppy-seed oil. Since peanut oil has been used at the clinic in bronchography for such a long period with only one proved reaction of this type, and since the only similar reactions reported in the literature occurred after the use of other oils, one must conclude tentatively at least that peanut oil is probably as good a base as the other oils currently in use.

The clinical importance of the reaction in this case was an apparent reduction of the patient's pulmonary reserve, requiring the use of oxygen therapy for a comparatively long period after operation. The process, as far as can be determined clinically, was a reversible one and the outcome was satisfactory. It would seem, in view of the reaction in this case, most desirable to empty the bronchial tree of iodized oil as quickly and completely as possible after bronchography. In addition, it would seem advisable to make roentgenograms of the chest prior to surgical intervention in all cases in which bronchography has been performed and to delay surgical intervention in those cases in which any considerable amount of residual iodized oil is observed in the roentgenograms.

REFERENCES

1. Sicard et Forestier: Méthode générale d'exploration radiologique par l'huile iodée (lipiodol), Bull. Soc. méd. d. hôp. de Paris 46: 463-469, 1922.
2. Rabinovitch, Jacob, and Lederer, Max: Lipoid Pneumonia, Arch. Path. 17: 160-168, 1934.
3. Wright, R. D.: Reaction of Pulmonary Tissue to Lipiodol, Am. J. Path. 11: 497-502, 1935.
4. Brody, Henry: Focal Lipid Granulomatosis of the Lung Following Instillation of Iodized Poppyseed Oil, Arch. Path. 35: 744-749, 1943.
5. Ballon, D. H., and Ballon, H. C.: The Effect of Injection of Lipiodol and the Rate of Its Disappearance in Normal and Diseased Lungs, Canad. M. A. J. 17: 410-416, 1927.
6. Fried, B. M., and Whitaker, L. R.: Intratracheal Injection of Iodized Oil; Experimental Studies, Arch. Int. Med. 40: 726-739, 1927.
7. Pinkerton, Henry: The Reaction to Oils and Fats in the Lung, Arch. Path. 5: 380-401, 1928.
8. Brown, A. L.: The Fate of Iodized Oil (Lipiodol) in the Lungs, Surg., Gynec. & Obst. 46: 597-601, 1928.
9. Bettman, R. B., Kelly, John, and Crohn, Nathan: The Effect of Intrabronchial Injections of Iodized Poppy Seed Oil 40 Per Cent; an Experimental Study on Dogs, Arch. Surg. 19: 471-477, 1929.
10. Bezançon, F., Delarue, J., and Valet-Bellot, M.: Le sort du lipiodol dans le parenchyme pulmonaire chez l'homme, Ann. d'Anat. Path. 12: 229-261, 1935.
11. Gowar, F. J. S., and Gilmour, J. R.: Changes in Lung Following Injections of Iodised Oil into Trachea, Brit. J. Exper. Path. 22: 262-273, 1941.
12. Chesterman, J. T.: Lipoid Pneumonia Due to Iodized Oil, J. Path. & Bact. 54: 385-386, 1942.
13. Boldrey, E., and Aird, R. B.: The Effects of Iodized Poppyseed Oil and Iodine-Chlorine in Peanut Oil in the Subarachnoid Space of Animals, J. Nerv. & Ment. Dis. 99: 521-533, 1944.

THE EFFECT OF PNEUMONECTOMY ON PULMONARY FUNCTION

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DESPITE the fact that pneumonectomy has been an accepted surgical procedure since 1933,[1] there have not been many reports on the changes in pulmonary function with pneumonectomy.[2-6] Often these reports have consisted only of the measurement of the function postoperatively and an estimation of "normal" function preoperatively. In the present study measurements of pulmonary function were made both pre- and postoperatively by means of external spirometry and bronchospirometry.

These studies of pulmonary function before and after pneumonectomy were done on patients at Temple University Hospital. External spirometry measuring the over-all function of both lungs was carried out on twenty-four patients. An evaluation of the ventilatory function at rest and during a period of voluntary maximum effort was made. In sixteen patients the division of function between the right and left lungs was determined prior to operation by means of bronchospirometry. This was done in order to estimate the functional impairment of the lung to be resected as well as to bring out possible undetected impairment of function of the contralateral lung. Pneumonectomy was performed in twenty-one instances for pulmonary neoplasm, and in the remaining three for extensive unilateral bronchiectasis. The patients ranged in age from 35 to 66 years, the average age being 53 years. There were seventeen men and seven women.

External spirometry was carried out with the patients in a basal condition, using a Roth-Benedict water spirometer. A record of quiet respiration was obtained over a period of 5 to 6 minutes; the spirogram thus obtained was used for analysis of the oxygen absorbed per minute, the respiratory rate, the depth of respiration (tidal air), and the average minute volume of respiration (M.V.R.), that is, the respiratory rate times the tidal air. The maximum breathing capacity was recorded after asking the patient to breathe as deep and as fast as possible, as though he had been running. The record was continued for a period of one-half minute during which time the patient was frequently encouraged to breathe deeper and faster. For the short period of recording the maximum breathing capacity and recovery the soda lime container was removed from the spirometer to eliminate the resistance of the lime itself and the resistance of one flutter valve. The maximum breathing capacity (M.B.C.) was calculated in terms of liters per minute. The breathing reserve at rest was derived. (M.B.C. – M.V.R.). The per cent breathing reserve was also calculated according to the formula

$$\frac{\text{M.B.C.} - \text{M.V.R.}}{\text{M.B.C.}} \times 100.$$

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Repeated determination of resting minute volume and maximum breathing capacity by this method on the same day, successive days, or within a few weeks showed remarkable constancy of ventilatory function, particularly with regard to the depth of respiration both during quiet breathing and during maximum effort.* It was, therefore, felt that it was valid to compare the results obtained by this method before and after pneumonectomy. These results cannot be compared with those obtained on the Douglas bag by other investigators, since the depth of respiration both during quiet breathing and during maximum effort appear to be greater on the spirometer, probably due to the greater resistance of the closed circuit.

External spirometry was done before and after pneumonectomy in all twenty-four cases. The postoperative studies were carried out two to three weeks after pneumonectomy in sixteen cases, and two months to two years later in nineteen cases.

Bronchospirometry was performed preoperatively on sixteen patients. A Gebauer twin spirometer was used. Originally a Zavod catheter was used; later a Norris catheter[7] was substituted for the Zavod, as we felt it gave more accurate results. The patients were not in a basal condition. Under local Pontocaine anesthesia and using fluoroscopic guidance the catheter was put in place with the tip in the left main bronchus. The procedure has been more fully described elsewhere.[7]

The division of function between the two lungs was calculated from the bronchospirometric record. This included the per cent of the total oxygen absorbed from the right and left lungs, respectively, and the per cent of the total volume of air moved by each lung. By referring these relative functions of each lung back to the resting oxygen absorption and tidal volume as determined by external spirometry under basal conditions, the probable resting function of each lung was estimated. The maximum breathing capacity of each lung was calculated from the percentage of the total tidal air moved by each lung and the total maximum breathing capacity as obtained by external spirometry. Such an estimation of the maximum breathing capacity of the separate lungs is valid only if the proportion of air ventilated by each lung is the same with a maximum ventilatory effort as during rest. Recent work has shown that this is not always so. For instance, in unilateral emphysema there may be a difference between the percentage of air ventilated by the involved lung during quiet respiration and during great respiratory effort.[8] It would seem, then, that our estimated figures for the maximum breathing capacity of the separate lungs preoperatively may be open to some question, but at the moment they are the best available.

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*A total of 130 tests were done on 45 individuals at intervals ranging from one-half hour to several months. The average variation in resting minute volume was 1.2 L., in maximum breathing capacity 7 per cent; the average variation in the depth of respiration during quiet breathing was 85 c.c. and during maximum effort 196 c.c. Using the figures obtained it was found that differences of less than 2.5 L. in resting minute volume, and of less than 15 per cent in maximum breathing capacity were insignificant. Likewise, a change of less than 200 c.c. in resting tidal volume or of 300 c.c. in the depth of respiration obtained during maximum effort was insignificant.

RESULTS

The results may be considered in two categories: the changes in the total pulmonary function after pneumonectomy and the changes in the function of the remaining lung (Tables I and II).

The changes in total function are shown in Table II. Seventeen patients were examined two to three weeks after pneumonectomy. In general, the respiration tended to be more rapid and somewhat less deep in the immediate postoperative period than prior to operation, but in only five instances was the respiratory rate above 20. In two cases of pulmonary suppuration prior to operation the respiratory rate dropped below 20 after removal of the diseased lung. Twenty patients were re-examined two to twenty-four months postoperatively. All except three had respiratory rates below 20. In almost all the patients who were studied both immediately postoperatively and then some months later the respiratory rates had decreased below the two weeks postoperative rate, although they were in some instances still slightly higher than the preoperative rates. The depth of respiration was often less postoperatively than it had been preoperatively. There was usually no significant change in the minute volume of respiration.

Preoperatively, the maximum breathing capacities ranged from 17.1 L. to 60.8 L. per minute. These values are far below the expected normals as estimated by Cournand.[5]* The resting breathing reserves (M.B.C. − M.V.R.) ranged from 9.9 to 52.7 L. The percentage breathing reserves ($\frac{\text{M.B.C.} - \text{M.V.R.}}{\text{M.B.C.}}$ × 100) preoperatively ranged from 42 to 88 per cent. Postoperatively the maximum breathing capacity usually decreased; there was a decrease in the depth of respiration during maximum ventilatory effort in all but one case (Case 10) and usually an increase in rate. In a few cases the increased rate compensated for the decreased depth so well that the maximum breathing capacity postoperatively actually closely approached or even exceeded the preoperative determination.

Changes in resting breathing reserve usually paralleled the changes in the maximum breathing capacity. Interestingly enough, after the immediate postoperative period there were eight patients in whom there was an increase and two patients in whom there was less than a 2 L. decrease in the breathing reserve after the removal of one lung. In the remaining nine patients the decrease in reserve ranged from 5 to 31 L.

Except, then, for the decrease in maximum breathing capacity (average decrease 23 per cent), the changes in the over-all resting pulmonary function picture with pneumonectomy were not great. However, the changes in the function of the remaining lung were often striking and indicative of compensatory adjustments to maintain the resting pulmonary function at its preoperative level.

With the patient in a basal condition the oxygen absorption of the remaining lung increased an average of 80 per cent. If the basal oxygen of the in-

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*For men: estimated normal M.B.C. (86.5—[0.522 × age]) × surface area in meters.[3]
For women: estimated normal M.B.C. (71.3—[0.474 × age]) × surface area in meters.[3]

TABLE I. RESULTS OF PULMONARY FUNCTION TESTS BEFORE AND AFTER PNEUMONECTOMY*

CASE NO.	SEX	AGE	TIME	O_2 USE (C.C./MIN.)			RATE	TIDAL VOLUME (C.C.)			M.V.R. LITERS	M.B.C. LITERS	B.R. LITERS	B.R. PER CENT	LESION AND OPERATION
				TOTAL	RIGHT	LEFT		TOTAL	RIGHT	LEFT					
1	F	57	Preop.	217	102 47%	115 53%	17	500	250 50%	250 50%	8.5	26.0	17.5	67	Carcinoma left lung Left pneumonectomy
			16 mo.		275		17		350		6.0	18.2	12.2	64	
2	M	63	Preop.	300	132 44%	168 56%	16	400	208 52%	192 48%	6.4	30.8	24.4	79	Carcinoma right lung Right pneumonectomy
			12 mo.			300	15			550	8.2	31.6	23.4	74	
			24 mo.			273	21			550	11.5	52.5	41.0	78	
3	M	47	Preop.	316	123 39%	193 61%	16	500	230 46%	270 54%	8.0	24.0	16.0	67	Carcinoma right lung Right pneumonectomy Empyema postop.
			3 wk.			315	17			550	9.4	16.2	6.8	42	
			3 mo.			237	15			500	7.5	18.0	10.5	58	
			12 mo.			253	16			450	7.2	22.0	14.8	67	
4	M	51	Preop.	188	123 65%	65 35%	6	1300	718 55%	582 45%	7.8	19.0	11.2	59	Carcinoma right lung Right pneumonectomy Empyema postop. Right thoracoplasty
			4 mo.			320	15			500	7.5	16.0	8.5	53	
			7 mo.			250	13			450	5.9	15.2	9.3	61	
			12 mo.			210	12			650	7.8	28.0	20.2	72	
5	F	37	Preop.	200	116 58%	84 42%	12	700	380 55%	320 45%	8.4	20.3	11.9	59	Carcinoma right lung Right pneumonectomy
			22 mo.			206	12			450	5.4	15.4	10.0	65	
6	M	58	Preop.	250	162 65%	88 35%	8	1000	750 75%	250 25%	8.0	57.0	49.0	86	Carcinoma left lung Left pneumonectomy Empyema postop.
			3 wk.		220		6		900		5.4	42.5	37.1	87	
			5 mo.		250		9		800		7.2	43.7	36.5	83	
7	M	42	Preop.	183	121 66%	62 34%	7	1150	830 72%	320 28%	8.1	60.8	52.7	87	Carcinoma left lung Left pneumonectomy Spread to mediastinum
			2 wk.		240		18		450		8.1	38.0	29.9	79	
			6 mo.		266		17		600		10.2	30.0	19.8	66	
8	F	42	Preop.	268	144 54%	122 46%	17	300	75 25%	225 75%	5.1	38.4	33.3	87	Carcinoma right lung Right pneumonectomy
			2 wk.			186	25			250	6.3	19.5	13.2	68	
			3 mo.			150	17			300	5.1	9.5	4.4	46	
			4 mo.			283	18			200	5.2	25.2	20.0	79	
			6 mo.			166	16			350	5.6	24.0	18.4	77	

9	F	47	Preop.	200	62 31%	138 69%	11	625	306 49%	320 51%	6.9	17.1	10.2	60	Carcinoma right lung Right pneumonectomy
			2 wk.			216	17			650	11.1	16.2	5.1	81	
			22 mo.			140	10			475	4.8	15.4	10.6	70	
			30 mo.			200	12			470	5.6	21.6	16.0	74	
10	F	41	Preop.	238	238 100%	--- 0%	24	400	400 100%	--- 0%	9.6	21.7	12.1	56	Far advanced bronchiectasis Left pneumonectomy
			2 wk.		226		10		650		6.5	23.4	16.9	72	
			5 mo.		150		20		850		17.0	33.3	16.3	67	
			18 mo.		250		21		600		12.6	29.4	16.8	57	
11	F	58	Preop.	288	259 90%	29 10%	13	700	490 70%	210 30%	9.1	29.4	20.3	71	Carcinoma left lung Far advanced tuberculosis left Left pneumonectomy
			7 mo.		233		12		700		8.4	22.5	14.1	63	
12	M	56	Preop.	300	212 74%	88 26%	23	450	324 71%	126 29%	10.4	36.8	26.4	72	Carcinoma left lung Left pneumonectomy
			2 wk.		217		24		400		9.6	32.4	22.8	70	
13	M	47	Preop.	200	88 44%	112 56%	10	1300	663 51%	637 49%	13.0	50.4	37.4	74	Carcinoma right lung Right pneumonectomy
			2 wk.			287	18			450	8.1	27.0	18.9	70	
14	M	44	Preop.	226	146 69%	80 31%	12	650	400 61%	250 39%	7.8	52.8	45.0	85	Carcinoma left lung Left pneumonectomy
			2 wk.		233		15		500		7.5	22.0	14.5	66	
15	M	35	Preop.	325			18	750			13.5	32.3	18.8	58	Advanced bronchiectasis Left pneumonectomy
			2 wk.		300		27		500		13.5	17.0	3.5	21	
			3 mo.		225		25		625		15.6	24.6	9.0	37	
			10 mo.		400		23		650		14.9	41.4	26.5	64	
16	M	61	Preop.	200			17	500			8.5	39.6	31.1	79	Carcinoma right lung Right pneumonectomy
			1 yr.			150	20			550	11.0	25.2	14.2	56	
17	M	60	Preop.	350			11	500			5.5	18.0	12.5	70	Carcinoma left lung Left pneumonectomy
			2 wk.		265		20		380		9.9	21.0	11.1	57	
			6 mo.		340		14		600		8.4	18.2	9.8	54	
			18 mo.		233		16		600		9.6	22.8	13.2	58	
18	F	52	Preop.	216			12	540			6.5	54.0	47.5	88	Carcinoma right lung Right pneumonectomy
			7 mo.			175	18			400	7.2	30.0	22.8	76	

*The oxygen use and tidal volume given for the right and left lungs preoperatively are based on the per cent division of function as determined by bronchospirometry.

M.V.R.—minute volume of respiration.

M.B.C.—maximum breathing capacity.

B.R. —breathing reserve (M.B.C.—M.V.R.).

% B.R.—$\frac{\text{M.B.C.—M.V.R.}}{\text{M.B.C.}} \times 100$

(Table I continued on following page)

TABLE I—CONT'D

CASE NO.	SEX	AGE	TIME	O_2 USE (C.C./MIN.)			RATE	TIDAL VOLUME (C.C.)			M.V.R. LITERS	M.B.C. LITERS	B.R. LITERS	B.R. PER CENT	LESION AND OPERATION
				TOTAL	RIGHT	LEFT		TOTAL	RIGHT	LEFT					
19	M	62	Preop.	216			29	500			14.5	25.0	10.5	42	Carcinoma left lung Left pneumonectomy
			2 wk.		160		19		425		8.2	11.4	3.2	28	
20	M	40	Preop.	280			14	550			7.7	41.8	34.1	82	Advanced bronchiectasis Left pneumonectomy
			6 mo.		312		11		550		6.1	29.7	23.6	79	
21	M	52	Preop.	300			17	450			7.7	17.6	9.9	56	Carcinoma right lung Right pneumonectomy
			2 wk.			330	20			400	8.0	12.0	4.0	33	
			3 mo.			250	15			450	6.8	16.5	9.7	58	
			6 mo.			240	17			450	7.6	18.2	10.6	58	
22	M	66	Preop.	180			10	800			8.0	55.2	47.2	86	Carcinoma right lung Right pneumonectomy
			12 days			233	14			500	7.0	27.0	20.0	74	
23	M	57	Preop.	276	210	66	18	550	430	120	9.9	39.0	29.1	75	Carcinoma left lung Left pneumonectomy
					75%	25%			78%	22%					
			2 wk.		350		25		400		10.0				
			3 mo.		250		21		350		7.4	40.0	32.6	82	
24	M	64	Preop.	243	110	132	12	900	530	370	10.8	56.0	45.2	81	Lymphosarcoma Left pneumonectomy
					47%	53%			59%	41%					
			2 wk.		276		16		700		11.2	27.3	16.1	59	
			2 mo.		333		14		750		10.5	32.6	22.1	68	

dividual were to remain constant, it would obviously follow that the remaining lung would increase its absorption of oxygen to the extent necessary to provide the amount formerly absorbed from the diseased lung. Theoretically, if half of the total oxygen were provided by each lung preoperatively, then postoperatively the remaining lung must necessarily double its oxygen uptake. Considering only those patients (Cases 2, 5, 6, 8, 9, 10, and 14) in whom the over-all oxygen absorption was approximately the same before and after operation, it may be seen that the increase in oxygen absorption from the remaining lung is inversely proportional to the per cent of the total oxygen provided by that lung preoperatively. For example (Case 2) when the remaining lung preoperatively was absorbing 56 per cent of the total oxygen, postoperatively its oxygen absorption was not quite doubled (1.8 times); when the oxygen absorption preoperatively was 46 per cent of the total oxygen (Case 8), the oxygen uptake by the remaining lung was a little more than doubled (2.3 times) postoperatively. When the oxygen consumption was increased greatly because of infection (Case 4), the increase in oxygen uptake from the remaining lung was almost five times the preoperative value.

The minute volume changes were not proportional to the changes in oxygen absorption; the oxygen absorption of the remaining lung increased more than did the minute volume. On an average, preoperatively, the uninvolved lung absorbed 100 c.c. of oxygen for every 3.7 L. of air moved; two weeks postoperatively it absorbed 100 c.c. of oxygen for every 3.4 L. of air moved, and several months postoperatively, 100 c.c. of oxygen for every 2.6 L. of air moved.

The depth of respiration (tidal volume) of the remaining lung increased except in one instance. During the immediate postoperative period the average increase in depth was 51 per cent and after several months the average increase in depth was 70 per cent. In one case the depth of respiration increased by 112 per cent. These changes in depth coupled with the usual increase in the rate of respiration produced an average increase in the minute volume of the remaining lung of 55 per cent.

The maximum breathing capacity *of the remaining lung* tended to increase postoperatively due in the main to an increase in the rate of respiration during maximum voluntary effort. Using the calculated preoperative values the increase in the depth of respiration of the remaining lung during maximum effort apparently amounted to no more than 300 c.c. with one exception when there was an increase of 570 c.c. In two patients the M.B.C. of the remaining lung decreased postoperatively. One patient had developed hemiplegia with marked muscular weakness, so that the rate of respiration during maximum effort was greatly decreased. The second patient had had extension of the bronchial carcinoma to the mediastinum and had received x-ray therapy over the mediastinal area. In this case there was a 56 per cent decrease in the depth of respiration during maximum effort.

DISCUSSION

Pneumonectomy in patients with little or no disease in the contralateral lung caused remarkably little change in resting oxygen absorption or the minute

TABLE II. COMPARISON OF THE MAXIMUM BREATHING CAPACITY

CASE NO.	TIME	MAXIMUM BREATHING CAPACITY					BREATHING RESERVE	BREATHING RESERVE	MEDIASTINAL SHIFT*	DYSPNEA
		TOTAL LITERS	RATE	DEPTH C.C.	RIGHT C.C.	LEFT C.C.	LITERS	PER CENT		
1	Preop.	26.0	20	1300	650	650	17.5	67	–	None
	16 mo.	18.2	26		700		12.2	64	–	None on 1 flight of stairs
2	Preop.	30.0	22	1400	720	680	24.4	79	–	On moderate exertion
	24 mo.	52.5	42			1250	41.0	78	+++	None on 1 flight of stairs Working in store 12-14 hrs. a day
3	Preop.	24.0	16	1500	690	810	16.0	67		On slight exertion
	22 mo.	22.0	22			1000	14.8	67	0	On hurrying up stairs Working as garage mechanic
4	Preop.	19.0	10	1900	1050	850	11.2	59		On walking
	12 mo.	28.0	28			1000	20.2	72	0	On walking
5	Preop.	20.3	14	1450	800	650	11.9	59		Difficult to evaluate "attacks" of dyspnea
	22 mo.	15.4	22			700	10.0	65	+++	On exertion
6	Preop.	57.0	30	1900	1450	470	49.0	86		On stairs
	5 mo.	43.7	38		1150		36.5	83	0	On stairs
7	Preop.	60.8	32	1900	1370	530	52.7	87		None
	6 mo.	30.0	50		600		19.8	66	–	At rest
8	Preop.	38.4	48	800	200	600	33.3	87		None
	6 mo.	24.0	32			750	18.4	77	+++	On stairs
9	Preop.	17.1	18	950	550	400	10.2	60		On exertion
	22 mo.	21.6	24			900	16.0	74	+++	Works 8 hr. day as a waitress; dyspnea only on 2 flights of stairs
10	Preop.	21.7	28	775	775	0	12.1	56		?
	18 mo.	29.4	28		1050		16.8	74	+++	None on stairs; does housework
11	Preop.	29.4	28	1050	730	320	20.3	71		None
	7 mo.	22.5	30		750		14.1	63	++	None on stairs
23	Preop.	39.0	26	1500	1170	330	29.1	75		On exertion
	3 mo.	40.0	40		1000		32.6	82	+	On stairs
24	Preop.	56.0	28	2000	1180	820	45.2	81		None
	2 mo.	32.6	46		710		22.1	68	+	On exertion; readily fatigued
15	Preop.	32.3	38	850			18.8	58		On walking
	10 mo.	41.4	46		900		26.5	64	+	None on walking but on 1 flight of stairs
16	Preop.	39.6	36	1100			31.1	79		On stairs
	12 mo.	25.2	28			900	14.2	56	+++	On stairs; unable to work
17	Preop.	18.0	20	900			12.5	70		On stairs
	18 mo.	22.8	38		600		13.2	58		On walking
18	Preop.	54.0	36	1500			47.5	88		None
	7 mo.	30.0	30			1000	22.8	76		None
20	Preop.	41.8	22	1900			34.1	82		On exertion
	6 mo.	29.7	22		1350		23.6	79	+	On exertion; does light work

TABLE II—CONT'D

CASE NO.	TIME	MAXIMUM BREATHING CAPACITY					BREATHING RESERVE LITERS	BREATHING RESERVE PER CENT	MEDIASTINAL SHIFT*	DYSPNEA
		TOTAL LITERS	RATE	DEPTH C.C.	RIGHT C.C.	LEFT C.C.				
21	Preop.	17.0	16	1100			9.9	56		On exertion
	6 mo.	18.2	20			700	10.6	58	+ +	None on 1 flight of stairs
12	Preop.	36.8	32	1150	820	330	26.4	72		None
	2 wk.	32.4	30		900		22.8	70	0	-
13	Preop.	50.4	18	2800	1430	1370	37.4	74		None
	2 wk.	27.0	30			900	18.9	70	+ +	-
14	Preop.	52.8	22	2400	1460	940	45.0	85		On exertion
	2 wk.	22.0	22		1000		14.5	66	+	-
19	Preop.	25.0	26	960			10.5	42		On walking
	2 wk.	11.4	19		600		3.2	28	+	At rest
22	Preop.	55.2	20	1500			47.2	86		None
	2 wk.	27.0	36			750	20.0	74		-

*As shown by roentgen examination.

volume of ventilated air. This lack of change resulted from adjustments of the remaining lung to the altered situation.

Absorption of oxygen from the one remaining lung increased sufficiently to meet the resting needs of the individual. Since oxygen absorption by the blood is a physicochemical process, the increase in oxygen absorption by the remaining lung of 80 per cent or more suggests that there has been an increase in the volume of blood flowing through that lung per minute. Such an increase in volume could be accomplished in two ways, by an increase in the rate of blood flow or by an increase in the functioning capillary bed of the remaining lung. The latter is the explanation which has been advanced at separate times by Tigerstedt,[9] Wiggers,[10] and Cournand.[5]

If the total capillary bed of the remaining lung does not change, and the functioning capillary bed increases as is suggested by the oxygen absorption, then the reserve or nonfunctioning capillary bed of that lung is decreased. One could postulate that the reserve capillary bed might no longer be as adequate to meet an increased cardiac output or an increase in blood volume as was the entire capillary bed of both lungs preoperatively. That the reserve of the remaining lung is not always adequate is suggested by the fact that 20 per cent of these patients with apparently normal hearts developed pulmonary edema with the increased stress of the first few postoperative days. However, recovery followed treatment and there has been no further evidence of pulmonary edema or heart failure in this group of patients.

The total volume of air ventilated per minute was changed insignificantly by pneumonectomy. This constancy of the over-all picture was maintained by means of a slightly more rapid rate of respiration coupled with an increased volume of air taken in at each breath by the remaining lung. The increase in the tidal volume of the uninvolved lung amounted to more than 100 per cent in a few instances.

On the whole, one was unable to predict too accurately from the maximum breathing capacity or the per cent breathing reserve what the patient's symptoms with regard to dyspnea were. Preoperatively there were two patients with breathing reserves of 85 per cent and 86 per cent who had dyspnea on moderate exertion. On the other hand, there was one patient with a breathing reserve as low as 67 per cent (17 L.) with no dyspnea.

All of the patients, three with breathing reserves below 11 L., successfully tolerated the operative procedure. There was no correlation between the preoperative breathing reserves and postoperative pulmonary edema when it occurred.

Pneumonectomy did not necessarily change the amount of dyspnea experienced by the patient during ordinary activity (not exercise). Five of the patients whose postoperative reserves ranged from 61 per cent to 70 per cent and whose x-ray films showed overdistention of the remaining lung, had no dyspnea except when hurrying against a cold wind. They did, of course, have a decreased exercise tolerance, but their normal activities did not often cause them to exceed it. Eleven patients who had been dyspneic on exertion preoperatively still had the same amount of dyspnea postoperatively. Their reserves ranged from 83 per cent to 56 per cent. They carried on their normal activities but performed tasks more slowly. An interesting observation on these patients was that although they did not complain of dyspnea they often had a noticeable increase in the rate of respiration when walking at a normal pace. One wonders if a patient with a pneumonectomy responds to increased oxygen need by an increase in respiratory rate rather than by an increase in the depth of respiration. One activity which seemed to cause definite dyspnea was the act of bending over. Such an act limits the motion of the diaphragm.

There were three patients in whom there was an improvement of effort capacity postoperatively. These individuals had had bronchiectasis, and they gained in weight and strength after the removal of the chronically infected lung. In only four patients was there any marked increase in dyspneic symptoms after pneumonectomy and each of these patients had other factors in addition to the pneumonectomy which impaired the respiratory function, such as hemiplegia with partial paralysis of the muscles of respiration, extension of the carcinoma into the mediastinum and into the other lung, or severe infection.

In summary, we have found that there may be remarkably little change in the over-all measurement of resting pulmonary function as a result of pneumonectomy. However, rather large compensatory changes do occur in the remaining lung; the resting depth of respiration may be as much as doubled, the minute volume may be tripled, and the oxygen absorption may be more than doubled to meet the resting oxygen demands of the individual. This means that the one remaining lung can successfully compensate for the loss of functioning lung tissue caused by pneumonectomy in most instances with but little increase in respiratory rate when the patient is at rest.

This does not mean that pulmonary function is within normal limits; in most of our patients it was definitely below normal, but it had also been below normal prior to operation. In most of the patients there was a lessened ability to increase the ventilation of the lungs upon demand, i.e., a decrease in the breathing reserve. In fact, what increase in ventilation there was on effort depended much more upon an increase in the rate of respiration than it had prior to pneumonectomy. However, the decreases in breathing reserve were associated with subjective dyspnea only if the individual was required to undertake some activity requiring considerable muscular effort, and since most patients undergoing pneumonectomy were in the older age group, it was not often that their normal activities were strenuous enough to cause this. The cases which showed considerable functional impairment after pneumonectomy usually had other factors complicating the postoperative course such as hemiplegia or spreading carcinoma.

SUMMARY

1. Pulmonary function studies have been compared before and after pneumonectomy in twenty-four patients.
2. Pneumonectomy produced little or no change in the over-all resting tidal volume, minute volume, and oxygen consumption of these patients.
3. Pneumonectomy usually reduced the maximum breathing capacity and the breathing reserve by reducing the depth of respiration during maximum respiratory effort.
4. This lack of change in over-all resting pulmonary function after pneumonectomy was due to compensatory adjustments of the remaining lung, namely: (a) an increase in tidal volume, (b) an increase in minute volume, and (c) an increase in the oxygen uptake.
5. There was little or no increase in the depth of respiration of the remaining lung during maximum respiratory effort. What increase occurred in the maximum breathing capacity of the remaining lung was due to an increase in the rate of respiration.

REFERENCES

1. Graham, E. A., and Singer, J. J.: Successful Removal of an Entire Lung for Carcinoma of the Bronchus, J. A. M. A. 101: 1371, 1933.
2. Cournand, A., and Berry, F. B.: The Effect of Pneumonectomy Upon Cardiopulmonary Function in Adult Patients, Ann. Surg. 116: 532, 1942.
3. Lester, C. W., Cournand, A., and Riley, R. L.: Pulmonary Function After Pneumonectomy in Children, J. THORACIC SURG. 11: 529, 1942.
4. Maier, H. C.: Cardiopulmonary Disturbances Associated With Mediastinal Displacement After Pneumonectomy, Surgery 15: 482, 1944.
5. Cournand, A., Himmelstein, A., Riley, R. L., and Lester, C. W.: A Follow-Up Study of the Cardiopulmonary Function in Four Young Individuals After Pneumonectomy, J. THORACIC SURG. 16: 30, 1947.
6. Birath, G., Crafoord, C., and Rudstrom, P.: Pulmonary Function After Pneumonectomy and Lobectomy, J. THORACIC SURG. 16: 492, 1947.
7. Norris, C. M., Long, J., and Oppenheimer, M. J.: Bronchospirography: Apparatus and Technique, J. THORACIC SURG. 17: 357, 1948.
8. Long, J. H., and Wester, M. R.: Unpublished Observations.
9. Tigerstedt, R.: Neue Untersuchungen uber die von dem linken Herzen herausgetriebene Blutmenge, Skandinav. Arch. f. Physiol. 19: 1, 1907.
10. Wiggers, C. J.: The Regulation of the Pulmonary Circulation, Physiol. Rev. 1: 239, 1921.

LACTATION FOLLOWING THORACOPLASTY AND PNEUMONECTOMY

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NONPUERPERAL lactation has been described frequently.[1, 2, 3] In the commoner instances it may occur for some months or years following weaning, at the time of the menopause, in cystic disease of the breast, in cases of ovarian tumors, and following removal of the ovaries. In the rarer cases it has been described following titillation and suckling of the breast in virgins, after a severe burn of the breast, in carcinoma of the pituitary gland, and at the time of menstruation. It has been described as occurring even in men with disease of the genitals or following prolonged suckling of the breast.

But, to our knowledge, the literature contains no reference to milk secretion following surgery of the thoracic cage. Since July, 1945, we have had ten such cases, the last one in June, 1948. The first one occurred following a primary anterior thoracoplasty. Nine cases followed a thoracoplasty and one case followed a pneumonectomy. Undoubtedly other such cases have occurred but have not been detected.

OPERATIVE TECHNIQUE

Because the operations are a primary factor in the production of lactation in this group, they will be described in brief. Four cases followed a first-stage posterior thoracoplasty, two cases followed a second-stage posterior thoracoplasty, three cases followed a first-stage anterior thoracoplasty, and one case followed a pneumonectomy.

In the first-stage posterior thoracoplasty, a long periscapular incision is made and the bony thorax reached by section of the latissimus dorsi, trapezius, and rhomboideus muscles. The origins of the serratus magnus muscle are separated from the upper five or six ribs and the scapula and the anterior chest wall are then retracted. The third and second ribs are removed subperiosteally up to the cartilage and including the associated transverse vertebral processes. The first rib is similarly removed including its cartilage. The periosteal beds are then formalinized and the wound closed in layers without drainage. The breast itself is not traumatized directly although a varying degree of local trauma does occur to it and many of its nerve fibers from the intercostals are undoubtedly torn and injured. Some degree of submuscular serosanguineous fluid always develops and may need occasional aspiration.

In the second-stage posterior thoracoplasty (done about twenty-one days after the first stage) the bony chest cage is reached through the lower part of the scar resulting from the first operation. The fourth and fifth ribs are re-

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moved subperiosteally up to the cartilages and the associated transverse vertebral processes are resected. The periosteal beds are formalinized and the wound closed in layers without drainage. A moderate degree of serosanguineous drainage occurs in the first several days postoperatively.

In the first-stage anterior thoracoplasty a perimammary incision is made. The bony chest cage is exposed by retracting the breast and pectoralis major muscle, and by freeing the origins of the pectoralis minor muscle from the ribs. Then long segments of ribs one, two, three, and four are removed subperiosteally to about the posterior axillary line. The cartilage of the first rib only is removed. The periosteal beds are then formalinized and the wound closed in layers without drainage. In these cases, the evidences of local trauma to the breast and skin are greater than in the posterior operation and there is usually a moderate amount of subpectoral serosanguineous exudate.

In the pneumonectomy patient a relatively short periscapular incision was made from the level of the fourth rib posteriorly around the scapula, and the sixth rib was removed subperiosteally. The pleural cavity was entered through the periosteal bed and the lung was removed. The wound was then closed in layers without drainage. There resulted a moderate degree of local trauma about the breast and the line of incision.

CASE REPORTS

CASE 1.—E. G., No. 11454, was a white woman, 41 years of age. She had far-advanced pulmonary tuberculosis predominantly on the left side with extensive cavities extending from ribs two to eight posteriorly. The first thoracoplasty stage was done through an anterolateral incision under cyclopropane-oxygen anesthesia on July 27, 1945; long anterior segments of the upper four ribs were removed subperiosteally. The second stage was done through the usual posterior approach Aug. 30, 1945, under cyclopropane and the posterior segments of the upper five ribs were removed. Two more stages were done later with a total removal of ten ribs and closure of the cavities.

The patient's menstrual periods began at 16 years of age, and occurred regularly every 28 days, lasting for five days. She had borne two children and had a considerable amount of breast milk each time. The breasts had now been dry for years. At the time of operation the patient was well nourished, plump, and had normal well-developed breasts. Her height was 65 inches, weight 151 pounds. Pelvic examination revealed no abnormalities.

She had a normal period from July 1 to 5. The first thoracoplasty was done July 27. She began to menstruate July 28. Three days later (July 31) her breasts became full and, on palpation, several cubic centimeters of creamy white free-flowing milk could be expressed from both breasts, predominantly the left. The subsequent menses and operations did not affect the lactation which continued for about six months. After two months the milk decreased in amount and the breasts became dry in January, 1946.

CASE 2.—M. P., No. 11308, a 34-year-old white woman, had far-advanced bilateral tuberculosis predominantly on the left side with an 8 cm. cavity extending from ribs three to seven posteriorly. The first thoracoplasty was an anterior stage done Nov. 15, 1945, under cyclopropane-oxygen anesthesia; the anterior segments of the upper four ribs were removed subperiosteally. The second stage was done Jan. 4, 1946, through a posterior approach, and a third stage Jan. 24, 1946. A total of seven ribs was removed with resulting cavity closure.

The patient began to menstruate at 11 years of age, and had a fairly regular 28-day cycle, with periods lasting 5 days. She has had three children, 15, 11, and 2 years of age. All were breast fed for thirteen months and she had abundant milk. After cessation of breast feeding the breasts became completely dry in several weeks. At the time of operation she was well nourished, short and stocky (height 63 inches, weight 143 pounds), and had well-developed normal breasts. Pelvic examination showed normal findings.

The patient had a normal menstrual period November 8 to 12. On November 15 the anterior thoracoplasty was done. Immediately afterward the left breast became enlarged and three days postoperatively she noted a fullness and soreness which she attributed to the operation. On November 20 about 400 c.c. of serosanguineous fluid were removed from the subpectoral space but the breast remained full and sore. On November 29, the patient awaking from sleep in pronation noted a large wet spot on her gown opposite the left breast. Palpation resulted in the expression of thick, creamy milk from both breasts but predominantly from the left. One could collect 10 to 20 c.c. from the left breast at any one time in a steady stream and about one-half as much from the right. She then felt (in retrospect) that she had probably had milk in her breast on the third postoperative day and was sure she could have expressed it had she realized milk was present. She also stated that her left breast felt as though it contained about one-half the amount of milk she had had when she nursed her babies. The lactation was unaffected by the next two operations or the subsequent menses. The breasts continued to have considerable milk for about eight months, then showed a gradual decrease. The left breast finally became dry twenty-seven months after the start of lactation and the right one after twenty-two months.

CASE 3.—F. C., No. 12175, a Negro woman, 32 years of age, had far advanced pulmonary tuberculosis predominantly on the left side with a 6 cm. cavity under ribs three to six posteriorly. The first thoracoplasty was done through the posterior approach on Dec. 11, 1945, under cyclopropane-oxygen-ether anesthesia and the upper three ribs were removed subperiosteally. The second stage was done Jan. 26, 1946, under nitrous oxide-oxygen-ether anesthesia. A third stage was done three weeks later and a total of eight ribs was removed.

Her menses began at 13 years of age and occurred in a regular 28-day cycle, lasting 5 days. She had been pregnant four times but miscarried each time in the fifth month. At no time did she have milk in her breasts, which were normal and well developed. Pelvic examination revealed no abnormalities.

The first thoracoplasty was done December 11, and the next day she began to have a normal period. Three days later (December 15) both breasts became full, especially the left one, and milk could be easily expressed from both. About 10 c.c. of thick creamy-white milk could be expressed from the left side at any one time and about 5 c.c. from the right side. Pressure forced the milk out in a stream. The menstrual period ended December 17. The next two operations had no effect on the lactation and the subsequent menses were normal. Both breasts continued to secrete milk freely for six months, then lessened gradually, and dried in twelve months.

CASE 4.—L. J., No. 12125, a white woman, aged 32 years, had far-advanced pulmonary tuberculosis predominantly on the right side with a 4 cm. cavity under ribs four, five, and six posteriorly. A right-sided thoracoplasty was planned. The first stage was done Jan. 17, 1947, through the posterior approach under Pentothal Sodium intravenously, followed by nitrous oxide, oxygen, and ether. Ribs one and two were completely removed and only the posterior half of the third. The second and third stages were done Feb. 7, 1947, and May 2, 1947, under similar anesthesia. A total of eight ribs was removed and the cavity closed.

The patient's menses began at sixteen years and were irregular until after the first pregnancy. The cycle was 30 days, the periods lasting 4 days. She had two children, aged 13 years and 11 years. She had a considerable amount of milk both times although she breast fed the first child only for three months. Her breasts had been dry for more than ten years. At the time of the operation she was well nourished and of normal build (height 67 inches, weight 120 pounds). The breasts were normal and pelvic examination showed normal findings.

Her menstrual period began January 12 and ended January 16. The first thoracoplasty was done January 17 and on January 19 the breasts became full and sore, and milk could be expressed. About 5 to 10 c.c. of creamy white milk could be easily expressed from the left breast (opposite to the side operated upon) and about 3 to 5 c.c. from the right one. The subsequent operations and menses had no effect upon the lactation although both the second and third stages were done one day prior to her menses. In August, 1947 (seven months later), only 4 c.c. thin yellowish milk could be expressed from the left breast and 2 c.c. thick creamy milk from the right one. The quantity lessened gradually and in December, 1947, both breasts became dry after lactating for eleven months.

CASE 5.—E. H., No. 12572, a 28-year-old white woman, had far-advanced pulmonary tuberculosis predominantly on the left side with a 4 cm. cavity under ribs three to five posteriorly. A left thoracoplasty was done. The first stage was performed March 21, 1947, through the posterior route under cyclopropane-oxygen-ether anesthesia. Two more stages were done later. A total of seven ribs was removed and the cavity closed.

The patient's menses varied from 25 to 30 days and lasted 4 days. She had one child, aged 4 years, who had been bottle fed although the patient had considerable breast milk. The breasts dried completely in six weeks. The patient was tall and slender (height 67 inches, weight 117 pounds) but had well-developed breasts. Pelvic examination showed normal findings.

The first thoracoplasty was done March 21; on March 23 her period began, and on March 25 milk was expressed from her breasts. She felt that the next two operations increased the fullness in both breasts slightly. The next period began April 29 and the one following on July 14. For the first week there was more milk in the left side, then the right one presented more and continued to do so. One could express 5 to 15 c.c. of creamy milk from each breast easily, and they would often drain spontaneously. In August the milk lessened in amount and in December, 1947, both breasts became dry after a lactation period of nine months.

CASE 6.—E. C., No. 12699, a 31-year-old Negro woman, had far-advanced pulmonary tuberculosis predominantly on the left side with a 7 cm. cavity under ribs three to six posteriorly. A first-stage left thoracoplasty was done by the anterior route May 24, 1947, under Pentothal Sodium, nitrous oxide-oxygen-ether, and the anterior segments of the upper four ribs were removed. The second stage was a posterior one and was done June 20, 1947, under cyclopropane. The third stage was done July 11, 1947, under nitrous oxide. A total of eight ribs was removed and the cavity closed.

The patient's menses began at 16 years and were very irregular for the first six years but then became regulated in a 28-day cycle, lasting 5 days. She had been pregnant twice, at ages 18 and 27 years, but aborted both times at three months. There was no lactation. At the time of her operation she was 60 inches tall and weighed 112 pounds. She was short and stocky and had normal well-developed breasts. Pelvic examination was normal.

She began to menstruate May 17 and the period ended May 24. The first thoracoplasty was done May 24. The next day the left anterior thoracic wall became swollen due to the operative trauma and subpectoral fluid. On May 27, the enlarged left breast became sore, and milk could be expressed. There was no milk in the right breast. The next two operations and menses had no effect on the lactation. One could express from 5 to 10 c.c. milk at any one time from the left breast. The right one was dry at all times. She continued to secrete milk until January, 1948, a period of seven months.

CASE 7.—L. D., No. 12698, a Negro woman, 22 years old, had far-advanced pulmonary tuberculosis predominantly on the left side with a 4 cm. cavity under ribs four to six posteriorly. A first-stage posterior thoracoplasty was done May 23, 1947, under Pentothal Sodium, nitrous oxide-oxygen-ether anesthesia with removal of the upper three ribs. The second stage was done June 20, 1947, under cyclopropane-oxygen-ether anesthesia with removal of ribs four and five. The third stage was done July 11, 1947, under Pentothal Sodium, nitrous oxide-oxygen-ether anesthesia with removal of ribs six, seven, and eight. The cavity then closed.

The patient's menses began at 14 years of age, recurring at intervals of 25 to 35 days, and lasting 6 or 7 days. She was not married but admitted having had sexual contact since the age of 17 years; however, she denied ever having been pregnant or having missed a period. She had never noted any secretion in the breasts. She was 65 inches tall and weighed 115 pounds. The breasts were nulliparous and well developed. The pelvic organs were normal on examination.

She had a normal period from May 4 to 10. The first-stage thoracoplasty was done May 23. No lactation occurred. The second-stage thoracoplasty was performed June 20, her period began June 22, and the next day both breasts became full and sore, and one could express several drops of milk from each breast. The period ended June 29. The next operation done July 11 produced no effect on the lactation. The next period occurred July 15 to 22.

Both breasts showed an equal amount of milk. One could express about 5 to 8 c.c. of freely flowing creamy milk during one or two minutes. Once, while she was lying face downward, some milk ran out spontaneously on the sheet from the right breast. In September, 1947, one could express only several thick drops of creamy milk from each breast. In January, 1948, both breasts became dry, after a period of seven months.

CASE 8.—B. P., No. 12724, a 22-year-old Negro woman, had far-advanced pulmonary tuberculosis, predominantly on the right side with two cavities measuring 3 cm. to 4 cm. under ribs four to seven posteriorly. A first-stage posterior thoracoplasty was done June 20, 1947, under cyclopropane-oxygen-ether anesthesia with removal of the upper three ribs. A second and a third stage were done July 11, 1947, and Aug. 8, 1947, under Pentothal Sodium, nitrous oxide-oxygen-ether anesthesia. A total of eight ribs was removed and the cavities closed.

The patient's menses began at 11 years of age with a 28-day cycle, lasting 5 days. The patient was single and denied ever having had sexual contact. She was of moderate build and height, and showed well-developed normal virginal breasts. A pelvic examination was not done but a rectal examination showed normal findings.

She had a normal period May 24 to 29. The first thoracoplasty was done June 20. A normal menstrual period started June 21, the breasts became tender June 22, and milk could be expressed from both breasts June 23. The menstrual period ended June 26. The second thoracoplasty was done July 11, and the menses occurred July 24 to 29. The third operation was done August 8 and the following period occurred August 23 to 28. The second and third operations and the following menses had no effect on the lactation.

The second day following the operation of June 20, the left breast became very tender but was normal in size. The right breast on the side operated upon was swollen due to some subpectoral fluid and operative trauma. The next day one could express several drops of milk from both breasts on several occasions. The milk was creamy and thick but was freely flowing. The right breast contained more milk than the left. Following the third operation the milk decreased in amount and, at that time, the right breast yielded several drops of thick milk and the left breast two or three drops of thin milk. By Sept. 18, 1947, both breasts were dry, after a period of three months.

CASE 9.—P. P., No. 12700, a 26-year-old Negro woman, had a far-advanced pulmonary tuberculosis. The left side was clear but the right side showed extensive disease throughout and a 4 cm. lower-lobe cavity under ribs seven to nine posteriorly. She was considered a favorable case for pulmonary resection. A right pneumonectomy was done May 23, 1947, under Pentothal Sodium, nitrous oxide-oxygen-ether anesthesia. A posterior periscapular incision was made extending to the anterior axillary line, the muscles were freed, and the sixth rib was removed subperiosteally; the pleural cavity was entered and the lung removed. This was followed later by a two-stage thoracoplasty.

The patient's menses began at 13 years of age, recurred every 28 to 35 days, and lasted about 3 days. She was married at 19 years of age and had had three pregnancies. Following the first two pregnancies she had only a small amount of milk for several weeks but following the third, which resulted in a miscarriage and fetal death in 1944, she had a considerable amount of milk. However, the breasts dried in several weeks. She was 62 inches tall and weighed 103 pounds. The breasts were small but normal. Pelvic examination presented normal findings.

She had a normal period April 26 to 29. The right pneumonectomy was done May 23, the menstrual period began May 24, the left breast became sore and full on May 26. Unfortunately it was not palpated for secretions. The period ended May 27. Another period began on July 1 and ended on July 4, and on this date the left breast again became sore and full and, on palpation, yielded about 3 c.c. creamy white milk. The right breast (the side operated upon) was dry. The patient states that (in retrospect) she was sure that she had had milk in the left breast on May 26, three days postoperatively, because it was sore and tender and felt "full." The subsequent thoracoplasty operations and menses did not affect the lactation. One could express 2 to 5 c.c. milk from the left breast several times daily but none from the right one. Milk was present until January, 1948, a period of about seven months.

CASE 10.—M. L., No. 12878, a white woman, aged 44 years, had far-advanced pulmonary tuberculosis with a 4 cm. cavity under ribs three to five posteriorly on the right side. A first-stage posterior thoracoplasty was done May 6, 1948, under Pentothal Sodium, cyclopropane-oxygen-ether, and the first, second, and posterior half of the third ribs were removed. The second stage was done May 28 with removal of the anterior half of the third rib and the entire fourth and fifth ribs. The third stage was done June 21 with removal of ribs six and seven. The cavity then closed. The anesthesia for the second and third stages was similar to that used during the first operation.

The patient's menses began at 16 years and had been of a regular type, every 28 days, lasting 5 days. In the last 4 years, however, they had been irregular and would occur anywhere from two to six weeks. She was married at 19 years and had had four pregnancies. Three were full term and one was an abortion at three months. One infant died in three weeks from "croup" but the other two did well and were nursed for 11 and 16 months, respectively. She had had an adequate supply of milk. Following weaning, the breasts dried in two months, and had been dry for ten years. Before her operation she was 67 inches tall and weighed 140 pounds. The breasts were normal and pelvic examination was normal. She stated that she had never had any soreness or fullness in the breasts prior to her menses.

She had one period from May 1 to 5. The first-stage thoracoplasty was done May 6. Daily palpation of the breast revealed no secretions. The next period began May 21 and ended May 25. The second thoracoplasty was done May 28 and on June 1 palpation revealed milk in both breasts. The third operation was done June 21 and she began to menstruate June 22 but the lactation was not affected. The patient had no fullness or tenderness of the breasts at any time. However, palpation yielded white creamy milk—about 4 to 8 c.c. from the right breast daily and about 3 to 5 c.c. from the left. At the present time (Sept. 1, 1948) the patient still yields similar amounts daily.

SUMMARY OF CASE REPORTS

The ten patients varied from 22 to 44 years of age and represented a normal cross section of height, weight, and body build. The breasts in all were well developed and showed no abnormalities. The other sex characteristics were normal. Apart from tuberculosis they had no systemic disturbances with the exception of one patient who had had syphilis and had been treated successfully. Five patients were white and five Negro, giving a relatively high percentage of Negro patients, since they formed only about 10 per cent of our thoracoplasty cases. Eight patients had been pregnant and only one denied sex contact. Their lactation history was normal as a group.

The amount of milk varied from several drops to 15 c.c. expressed at any time, and the daily production varied from 5 to 25 c.c. In all cases, the secretion showed the color, consistency, and taste of milk or creamy milk. In three patients, the milk flowed spontaneously on several occasions. The color and creaminess varied from one patient to another and from one time to another in the same patient. It showed an occasional variation in the two breasts. In five of the patients, milk secretion would not have been detected if proper palpation of the breast had not been done or if there had been no pressure on the breasts.

Table I summarizes the features of the lactation with respect to the amount of milk produced by each breast and the duration of the lactation. One patient had bilateral and equal milk secretion; five patients secreted more milk from the breast on the side operated upon; two patients secreted more milk from the side not operated upon; one only on the side operated upon; and the pneumonectomy patient only from the side not operated upon. The duration of secretion varied from three to twenty-seven months, with an average of about ten months.

Unfortunately, a sufficient number of detailed milk analyses were not made. The secretion had a milky or creamy taste and "soured" on standing for a day. Numerous fat globules were present microscopically and by stain. Analysis of the pooled sample done by the late Dr. P. L. MacLachlan of the Biochemistry Department showed the presence of protein, lactic acid, and large amounts of fat containing unsaturated fatty acids. When soured and shaken with water a precipitate occurred which resembled butter, and which was highly soluble in chloroform and absorbed iodine. The milk of Patient M. L. (Case 10) showed 2.6 per cent butter fat, 4.96 per cent lactose, casein, and reducing sugar.

TABLE I. FEATURES OF THE LACTATION

CASE	1	2	3	4	5	6	7	8	9	10	TOTAL
White	x	x		x	x					x	5
Negro			x			x	x	x	x		5
Posterior thoracoplasty			x	x	x		x	x	Resection	x	7
Anterior thoracoplasty	x	x				x					3
Lactation after second stage							x			x	2
Side operated on	L	L	L	R	L	L	L	R	R	R	R4 L6
Bilateral and equal lactation							x				1
More milk on side operated upon	x	x	x					x		x	5
More milk on side not operated upon				x	x						2
Milk only on side operated upon						x					1
Milk only on side not operated upon									x		1
Approximate daily yield, c.c.	10	40	25	15	30	15	20	5	15	10	
Duration, months	6	27	12	11	9	7	7	3	7	–	

UNIMPORTANT FACTORS

The patients varied in height from 60 inches to 67 inches and in weight from 103 to 151 pounds; two patients were slender in build, four were of medium build, and four were of stocky build. The breasts in all were well developed and normal. None had other systemic diseases or extrapulmonary tuberculosis. The diet was regular and somewhat high in protein. The blood counts, blood type, Rh factor, and blood coagulation factors were not significant. The urinalyses were normal in all cases. Preoperative medication included barbiturates and Dilaudid. Seven patients had cyclopropane-oxygen-ether anesthesia and three had Pentothal Sodium intravenously, followed by nitrous oxide-oxygen-ether. During the operation, blood, saline, and glucose were given to all patients. Stimulants were used in only two cases and included Adrenalin, cortin, ephedrine, and Neosynephrin. Postoperatively, narcotics, sedatives, and penicillin were used. Early ambulation was practiced and the patients were encouraged to get out of bed one to three days postoperatively. The postoperative fever was within expected limits. The dressing appeared to have no pressure effects on the breasts.

IMPORTANT FACTORS

All patients were in the active menstrual age. The five Negro women formed an unusually high percentage as the great majority of the operations we have done have been on white women. The three anterior thoracoplasties also formed a relatively high number as this type of operation is done in less than 10 per cent of our thoracoplasty cases. Seven cases followed the first-stage thoracoplasty and two followed a second stage.

The extent of surgical trauma is undoubtedly great and is to be expected following the section and freeing of so many large muscles and the subperiosteal removal of the ribs. There is always some collection of serosanguineous fluid submuscularly. The skin may occasionally show evidence of bruising. The processes of repair go on for some months. The breast tissue is not directly traumatized and the indirect trauma (retraction) is not very great. Undoubtedly, there must be considerable trauma to the intercostal nerves and fine branches although no paresthesias or anesthesias were noted.

When all the possible etiological factors are reviewed, the three that are most prominent are the day of the operation, the date of the menstrual onset, and the date of lactation. Table II shows the relationships between them. In all cases, lactation followed the operation in two to four days—two days in one case, three days in five cases, and four days in four cases. In six cases the expected menses began one or two days after the operation. In four cases the menses occurred seven days, seven days, seven days, and five days prior to the operation and were completed three days, three days, two days, and one day prior to the operation. The last day of the period appeared to have no significance.

THEORETICAL CONSIDERATIONS

Since the menstrual cycle, lactation, and the operation are closely connected, the physiology pertaining to them will be reviewed briefly. There is so much disagreement at present regarding the status and action of the hormones that only the more accepted views will be mentioned.[4, 5]

Following the onset of the menstrual period, the pituitary gonadotrophin acts first upon the ovarian follicle to produce estrogens and maturation of the ovum and later upon the corpus luteum to produce progesterone. The pituitary then becomes inactive due either to an innate rhythm or to an inhibition by the high estrogen level. This is followed by a rapid drop in the production of the ovarian hormones, and menstruation begins. During the premenstrual phase the breasts become enlarged and tender, and the ducts and alveoli proliferate and show some serous secretion. The estrogens develop the ducts and the progesterone the alveoli. When the menstrual period begins the breasts show regressive changes which continue for about a week. Although there is no mention of lactogenic hormone being formed during the cycle some recent experiments suggest that a lactogenic hormone may be necessary for the development of the corpus luteum.[4]

TABLE II. TIME RELATIONSHIPS BETWEEN THE DAY OF THE OPERATION (O), BEGINNING OF THE MENSTRUAL PERIOD (M), AND BEGINNING OF LACTATION (L)

CASE	1	3	8	9	5	7	2	6	4	10
Day 1	O	O	O	O	O	O	M	M	M	M
2	M	M	M	M						
3					M	M				
4			L	L		L				
5	L	L			L					
6									O	
7										
8							O	O	L	O
9										
10										
11							L	L		
12										L

When pregnancy occurs, the chorionic tissue produces gonadotrophin, estrogen, and progesterone. The last two hormones increase to a very high level, particularly in the terminal phase of pregnancy, and their production may reach a height of 20 to 50 times that seen maximally in the menstrual cycle. Following the removal of the placenta the hormones disappear within several days.

As a result of the stimulation of the mammary glands by the estrogen and progesterone during pregnancy, the ducts and alveoli show hyperplasia and hypertrophy and, toward the end of pregnancy, become filled with a secretion resembling colostrum. True lactation appears three to four days following childbirth. It is believed that the drop in the estrogen level following childbirth stimulates the pituitary to produce lactogenic hormone. The lactogen then initiates lactation in a properly prepared breast. Once started, the continuation of lactation is maintained by the mechanical act of suckling which stimulates the pituitary through the nerve pathways and causes further production of the lactogenic complex of hormones.

It is to be noted that the curves for gonadotrophin, estrogens, and progesterone have many similarities during the menstrual cycle and during pregnancy, although the former are on a much lower level. The role of lactogen in the menstrual cycle is not clear.

As mentioned, postpuerperal lactation is initiated by the lactogenic hormone in a breast properly prepared and developed by estrone and progesterone; it is maintained by the further production of lactogenic hormones as a result of stimulating the pituitary by the neurogenic mechanical act of suckling. One may conjecture that if the breast tissue were adequately prepared and if the neurogenic stimulus were sufficiently powerful, lactation might occur even during the menstrual cycle. Such an adequate preparation of the breasts may result from either an unusually high estrogen-progesterone level, a breast tissue unusually sensitive to normal levels, or both factors. The lactogenic hormone factor may be present normally during the menstrual cycle and be enhanced by the neurogenic stimulus, or a powerful neurogenic stimulus may in itself cause the pituitary to produce the hormone.

In this group of ten cases, no hormonal assays were made and we do not know whether these patients had a high estrogen-progesterone level or whether the breast tissue was unusually sensitive to normal levels of the hormones or whether both factors were present. The neurogenic stimulus to lactation was presumably supplied by the operation with its attendant stimulation of the nerve endings in the breast. The glandular elements are supplied by the fourth, fifth, and sixth intercostals and the accompanying sympathetic fibers; the skin is supplied by the anterior and lateral cutaneous branches of the second to the fifth intercostals and the supraclavicular branches of the cervical plexus. The maintenance of lactation for some months may be explained by the continued mechanical stimulation of the nerves by the processes of repair.

Since only the hormones usually present in the menstrual cycle are involved and since the operation (neurogenic factor) resulted in milk secretion, it is highly probable that lactogenic hormone may be present normally during the menses. Ordinarily, the lack of lactation during normal menses may be due to the small amount of lactogen, the lack of adequate preparation of the breast tissue, or both.

On the basis of this theory the secondary factors of significance will be explained. The high proportion of Negro women suggests that they have either a higher hormonal level or a more sensitive breast tissue, or both. The occurrence of lactation among both parous and nulliparous women and even in a virgin shows that no hormones other than those occurring normally in the menstrual cycle probably take part in the production of lactation. The high proportion of anterior thoracoplasties in this series is due probably to the fact that the damaged nerve fibers of the breast are more intensely stimulated in them than in the posterior operations. Seven out of the nine thoracoplasty patients lactated following the first stage at which not only the first, second, and third ribs were removed but in which the serratus magnus origins were separated from the upper five ribs, thus disrupting many of the nerve fibers to the breast. In two patients the first thoracoplasty operation did not produce sufficient neurogenic stimuli but the subsequent second stage apparently added enough stimuli to cause lactogenic production and secretion of milk. The low incidence of lactation in pneumonectomies is due probably to the fact that the nerve fibers to the mammary glands are only little disturbed either directly by the operation or indirectly later by the exudative and reparative processes. It is more difficult to explain the exact mechanism which occurred in Cases 2, 4, 6, and 10 in which the menses began and ended prior to the operation. It is possible that in them the level of ovarian hormones was still high during the menstrual period and dropped just before the operation.

This theory may also explain some of the abnormal causes of lactation mentioned in the first paragraph in which the neurogenic factor is represented by such trauma as titillation and a burn.

SUMMARY

1. Ten cases of lactation are described in nonpuerperal women following thoracic operations. Nine followed extrapleural thoracoplasty and one followed a pneumonectomy.

2. It is believed that the explanation of the lactation lies in the same hormonal factors present during the normal menstrual cycle, pregnancy, and lactation.

3. The lactogenic hormone factor usually resulting from the mechanical stimulation of the nerve fibers of the breast by the act of suckling was supplied, in these cases, by the operation.

4. It is possible that lactogenic hormone may be present normally during the menstrual cycle.

REFERENCES

1. Geschickter, C. F.: Diseases of the Breast, ed. 2, Philadelphia, 1945, J. B. Lippincott Company.
2. Blum, D. M., and Smyth, A. M.: Abnormal Lactation, J. Iowa M. Soc. 20: 206-214, 1930.
3. Richerand, A.: Elements of Physiology, Philadelphia, 1818, Thomas Dobson and Son.
4. Fulton, J. R.: Howell Textbook of Physiology, ed. 15, Philadelphia, 1947, W. B. Saunders Company.
5. Folley, S. J.: The Nervous System and Lactation, Brit. M. Bull. 5: 142-148, 1947.

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THE SURGICAL MANAGEMENT OF PULMONARY COCCIDIOIDOMYCOSIS IN FOCALIZED LESIONS

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Coccidioidomycosis is a highly infectious fungus disease with widespread endemic areas in West Texas, New Mexico, Arizona, Southern California, and the San Joaquin Valley of California. Almost all of the reported patients from North America have either visited or resided in one of these areas, but since vast numbers of soldiers were trained in these regions, patients who contracted the disease while in the Armed Services are now being discovered throughout the country.

The disease exists in a primary form which is usually self-limited and in a disseminated form which is fatal in almost one-half of the cases. The primary form is a disease of the respiratory system. It occurs from eight to twenty-one days following exposure.[1] Symptoms are present in only 40 per cent of the cases. If symptoms occur, they may be very mild and mistaken for a common cold or they may be severe with malaise, fever, chest pain, productive cough, and hemoptysis.[2, 3, 4] Even if there are symptoms, there may be no demonstrable chest lesion and only about one-fourth of the patients develop the disease in a form characteristic enough to be diagnosed clinically.[2] When a pulmonary lesion is present, it is at first inflammatory and if it heals at this stage there is no residual lung pathology. A few lesions progress from inflammation to suppuration and granuloma formation and since these lesions are destructive in nature they produce scar tissue when they heal. All of these lesions do not heal promptly. They may progress and spread to produce the disseminated form of the disease or they may form a focalized pulmonary infection either by remaining as a definite granuloma or by excavating to form a cavity. These focalized lesions may exist long after the initial acute pulmonary disease has subsided and are the most common form of the disease seen outside the endemic

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areas. Cavitation occurs in approximately 5 per cent of the clinically diagnosed cases.[3, 4] Most of the cavities probably close within several months if the patients are confined to bed. Some persist after prolonged bed rest, phrenic paralysis, pneumothorax therapy, or artificial pneumoperitoneum. Cavities may recur suddenly after closure has taken place, and even if cavitation persists, the patient can usually lead a normal life with few symptoms.[6, 7] Chronic focalized solid lesions are more common than cavitation during the acute phase of the primary disease, but most of these lesions regress completely or become inconspicuous on roentgenograms.[8] We have seen the large pulmonary granulomas less frequently than cavities.

Dissemination occurs in only one infection in 400.[2] When it does occur, it is usually as a progression of the primary form of the disease without significant regression of the initial symptoms. The symptoms become more severe with fever, weakness, and weight loss predominating. Suppurative and granulomatous lesions may spread in the lungs or throughout the entire body. Dissemination sometimes occurs after the primary infection has subsided, but apparently as the asymptomatic period grows longer, the probability of dissemination becomes less even in cases in which definite lesions persist.[2, 5]

PRESENTATION OF CASES

We have performed surgery on a total of thirteen patients having coccidioidal infections with focalized pulmonary lesions. Nine of the patients had persistent cavitation for which lobectomy was performed and four had rounded granulomatous lesions which were removed by wedge resection of the lung. All of the patients were soldiers or veterans and either had been stationed in endemic areas or had visited these areas. They were all white men; the youngest was 22 and the oldest 36 years.

The four patients with persistent granulomatous lesions in the pulmonary tissue were not ill at the time of operation. The lesion was discovered on a routine chest roentgenogram in each case, although two of the patients gave a history of episodes of pleuritic pain on the side of the lesion and had been bothered by mild chronic productive coughs. The other two patients had been asymptomatic. The diagnosis was not established preoperatively in any of the four cases, although coccidioidomycosis was suspected in three.

The nine patients with persistent cavitation were all symptomatic. They complained of a chronic cough which was productive except in one instance, but in no case was the cough severe and none of the patients produced more than one cupful of sputum daily. Eight of the nine patients complained of weakness and fatigue, often to a marked degree; it was the chief complaint in four of the cases. The pain was always of a pleuritic nature, was intermittent, and was usually severe while present. Dyspnea was complained of by six patients but it was mild in five of these cases and only moderate in the sixth. When hemoptysis occurred it was never severe but, on the other hand, there was usually more than tingeing of the sputum. All of the patients presenting this symptom had expectorated from one ounce to one cupful of bright red blood upon several different occasions. Three patients had chronic low-grade fever with periods of intermission but elevations above 101° F. were rare. Weight loss was a symptom in the same group that had fever; they had averaged approximately fifteen pounds loss. Six of the patients complained of symptoms which would not allow normal activity. These incapacitating symptoms had been evident from twelve to sixty-four months and hospitalization had been necessary an average of one year prior to surgery. All six of these patients complained of a persistent weakness and fatigue, and five had frequent episodes of hemoptysis. The chief complaint in four of the patients was ease of fatigue, while the other two complained of frequent episodes of hemoptysis in which 50 to 250 c.c. of blood would be expectorated. In addition, four of these patients had frequent episodes of pleuritic pain and three had chronic low-grade fever. Two case histories illustrate the characteristic course of the disease in patients having lobectomy.

CASE 1.—This 29-year-old soldier was born in Bowie, Texas, but was never in an endemic area until early in 1946 when he visited West Texas. While in this area he was in a sandstorm. In July, 1946, he had the sudden onset of pleuritic pain in the left chest and produced some blood-tinged sputum. A roentgenogram of the chest was reported as normal and the symptoms regressed in a few days. He continued to have pleuritic pain intermittently and a chest x-ray picture taken in November, 1946, showed cavitation in the left mid-lung field. He was hospitalized, the pain increased in intensity, and despite bed rest the cavity increased in size and the hemoptyses became more frequent and more severe. On several different occasions he produced as much as one cupful of bright red blood. He developed a cough which was productive of 15 to 30 c.c. of gray sputum daily. Many sputum examinations were negative for acid-fast bacilli but positive cultures of *Coccidioides immitis* were obtained repeatedly. Both the tuberculin and the coccidioidin skin tests were positive. His poor response to bed rest over a period of seven months was thought to be sufficient reason for resection of the lesion, and the left upper lobe was removed July 1, 1947. At operation pleural adhesions were noted overlying the area of cavitation.

The pathologic examination of the excised lobe revealed a cavity which measured 6 by 3 by 3 cm. A bronchus communicated with the cavity but this was plugged with necrotic tissue and the cavity contained air under pressure. The inner wall was of a caseous and necrotic nature and there were several areas of granulation tissue in the wall. The outer wall of the cavity was composed mainly of fibrous tissue. There were many small nodules palpable throughout the lung tissue. On microscopic examination mycelial forms of the fungus were seen but there were no spherules present. There was a chronic granulomatous pneumonitis in the surrounding lung, and nearby bronchi were involved in a chronic suppurative bronchitis. The multiple small nodules palpable in the lung were granulomatous foci but no fungi were seen in any of them. He had some atelectasis of the left lower lobe on the second postoperative day but he responded well to bronchoscopic aspiration. The lower lobe expanded to fill the entire left thoracic cage and he was returned to duty two months following surgery. Ten months after operation the patient was asymptomatic and doing general military duty.

CASE 2.—This 24-year-old white man was born in Minnesota. He was stationed in an endemic area of Arizona from October, 1943, until March, 1944. One year after leaving this area he developed a dry cough and two months later he first noticed blood-tinged sputum. In July, 1945, while overseas there was a gross hemoptysis and he was hospitalized. At that time he was ten pounds underweight and he complained of weakness and ease of fatigue. X-ray examination revealed a cavity in the right upper lung field measuring 1.5 to 2.5 cm. He arrived at Fitzsimons General Hospital Aug. 20, 1945. At that time there was no hemoptysis but he still had a chronic nonproductive cough and complained of marked fatigue.

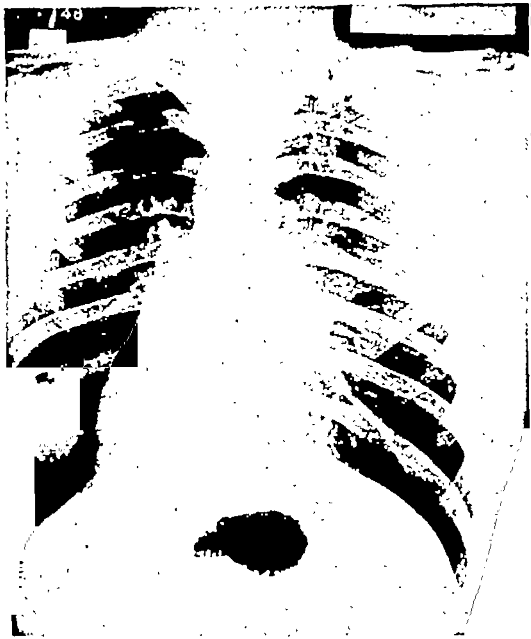

Fig. 1.

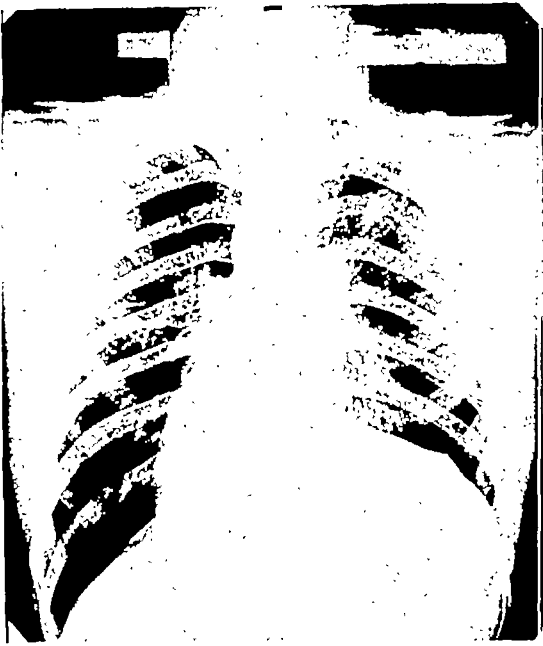

Fig. 2.

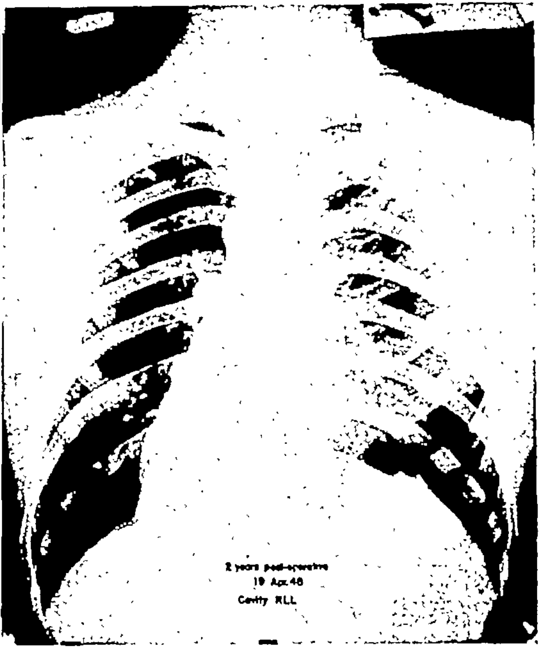

Fig. 3.

Fig. 1 (Case 2).—Cavity, right upper lobe.
Fig. 2 (Case 2).—Two months postoperatively; suggestive lesion in upper lung field which excavated two years later.
Fig. 3 (Case 2).—Cavity, two years postoperatively.

On repeated examinations *C. immitis* was cultured from the sputum and no acid-fast bacilli could be found. He was transferred to another hospital in August, 1945, where despite bed rest the sputum again became blood tinged, and on three occasions in the next four months he had episodes of gross hemoptysis. He continued to have a chronic low-grade fever. He was transferred back to Fitzsimons General Hospital Feb. 27, 1946 (Fig. 1). At this time the cavity was unchanged, the coccidioidin skin test was weakly positive, and the blood serology* was reported as being positive but of low titer, indicating that the process was well localized. Because of the persistence of severe symptoms after nine months hospitalization, it was decided that a lobectomy should be performed. The right upper lobe was removed April 22, 1946 (Fig. 2). At the time of operation pleural adhesions were encountered over the area of the cavity. No abnormality was noted in the remaining lower and middle lobes. On gross examination the cavity measured 2.5 by 2.5 by 3.5 cm. It was empty except for a few drops of mucoid material. Direct examination of this material revealed mycelial forms of *C. immitis* with chlamydospores, and cultures were positive for *C. immitis*. On examination of the prepared slides both forms of the fungus were seen. There were numerous miliary nodules in the surrounding lung tissue which were composed of central giant cells with surrounding epithelioid cells. No fungi were observed in these areas. There was much fibrosis about the lesion. The lining of the cavity was composed of squamous metaplasia epithelium, ciliated epithelium, granulation tissue, and caseous material. There was a bronchitis involving the bronchi communicating with the cavity. The postoperative course was uneventful. The remaining right lung expanded to fill the entire right thoracic cage. Two months following surgery he was asymptomatic and had gained ten pounds. He remained asymptomatic until March, 1948, almost two years after the lobectomy, when he began to tire easily and have a productive cough. He was hospitalized after producing bloody sputum, and chest roentgenograms showed a cavity in the right lower lobe measuring 3 cm. in diameter. No acid-fast bacilli were discovered in the sputum, but many cultures of *C. immitis* were obtained (Fig. 3). A review of the immediate postoperative roentgenograms reveals a circumscribed area of increased density in the re-expanded lower lobe which is the site of the present cavitation.

These two cases are representative of the six cases with cavitation and debilitating symptoms. The other four patients gave similar histories. Surgery was accomplished without difficulty and there were no immediate complications. Three of the nine patients had symptoms which had been noticed but were not severe enough to keep them from their work. One of these cases is interesting because serial x-ray views were obtained from the time the acute pulmonary infection started. A cavity was seen to develop and then close, only to reopen after two years. The latter case history is as follows:

CASE 3.—This 31-year-old white man, a soldier, made frequent trips into the lower San Joaquin Valley during the summer of 1941. In July, 1941, he developed a pleuritic type of pain involving both sides of the chest and reported to the hospital for treatment. X-ray examination showed a small diffuse lesion in the apex of the right lung and another small lesion in the left lower lung field which soon cavitated (Fig. 4). After two months he was discharged from the hospital and returned to his work as an x-ray technician. The only symptom was a mild chronic productive cough. Frequent roentgenograms were taken and in 1942 the cavity in the left base was not discernible (Fig. 5). In 1943 the lesion in the right apex was more discrete. In 1944 the lesion in the left lower lobe suddenly reappeared and by 1945 it was larger and showed a central area of rarefaction (Fig. 6). In February, 1947, he was hospitalized because of severe pleuritic pain and at this time there was an area of cavitation 2.5 cm. in diameter in the left lower lobe. The small nodule in the right apex had not changed in appearance in four years. No acid-fast bacilli were revealed after many sputum examinations but there was one positive culture for *C. immitis* in thirteen examinations. Both the tuberculin and the coccidioidin skin tests were positive to a marked degree. Blood serologic examinations* for coccidioidomycosis were negative. A short trial of artificial pneumoperitoneum produced no effect on the cavity. He remained asymptomatic except for a chronic cough productive of small amounts of sputum and intermittent chest pain. A lobectomy was advised because of the long-standing cavitation. This operation was performed Oct. 2, 1947. At the time of surgery, pleural adhesions were

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*Performed by Dr. C. E. Smith.

Fig. 4.

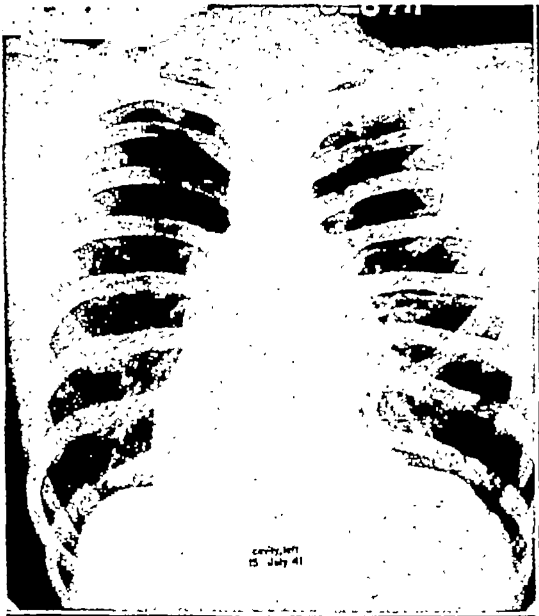
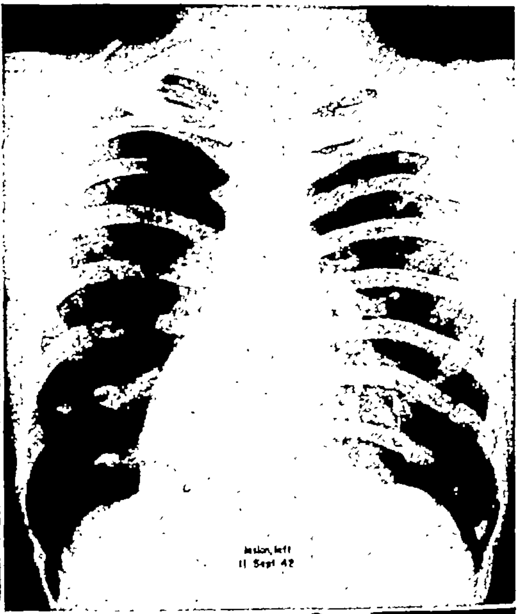


Fig. 5.



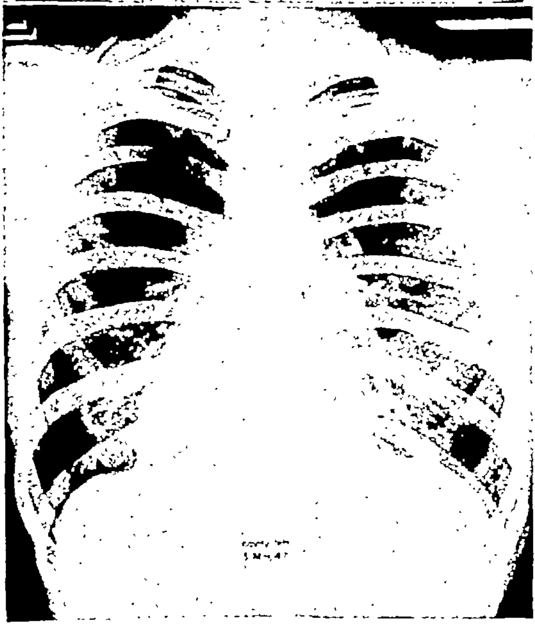


Fig. 6.

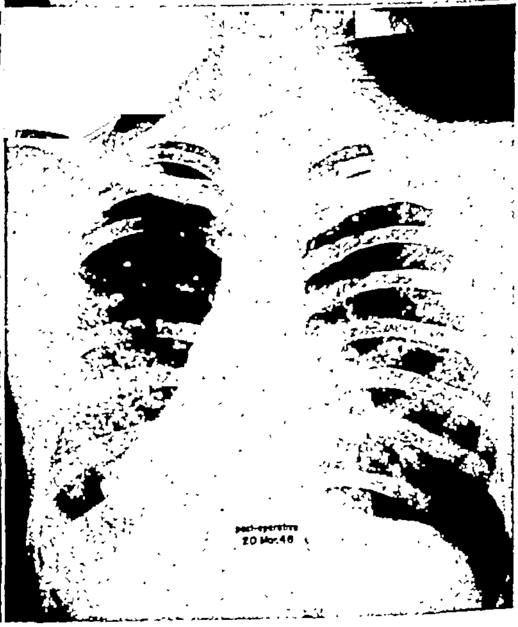


Fig. 7.

Fig. 4 (Case 3).—Lesion, right upper lobe; cavity, left lower lobe.
Fig. 5 (Case 3).—Cavity, left lower lobe not discernible.
Fig. 6 (Case 3).—Cavity, left lower lobe is larger.
Fig. 7 (Case 3).—Five months postoperatively, residual lipiodol.

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*Performed by Dr. C. E. Smith.

noted over the area of the cavity. There was no gross involvement of the upper lobe. Upon pathologic examination it was discovered that the cavity contained spherules of *C. immitis*. The cavity was surrounded by a fibrous zone 0.2 cm. thick and was lined by an area of caseation necrosis which at some points extended through the fibrous walls. Scattered about the cavity were miliary granulomas composed of epithelioid cells and Langhans' giant cells. Spherules of *C. immitis* were found in these satellite granulomas. He had an uneventful postoperative course and was returned to full military duty three months after surgery. He is asymptomatic seven months after surgery and there is no evidence of progression of his disease (Fig. 7).

Another patient with only moderate symptoms had a routine chest x-ray picture made and was discovered to have an area of cavitation in the upper lobe on the right. He gave a history of having had frequent colds and a moderate cough associated with increased ease of fatigue and intermittent chest pain over a period of four to five months. He was hospitalized and the diagnosis of coccidioidomycosis established by a positive culture of *C. immitis* from the sputum and by a positive coccidioidin skin test. There were no changes in his symptoms or in the size of the cavity after thirteen months of hospitalization, and a lobectomy was advised. Lobectomy was performed on another patient who had no symptoms other than a chronic nonproductive cough. He had a cavity in the left upper lobe measuring 6 cm. in diameter which had thick walls and contained a fluid level.

The round granulomatous lesions were excised with ease in every instance. Only one case had pleural adhesions and these were limited to the area of the lesion. The nodules were all situated near the periphery of the lung although the lesion was actually subpleural in only one. The superficial location allowed them to be easily removed by wedge resection.

All nine of the lobectomies were performed without technical difficulties. There were pleural adhesions overlying the areas of cavitation in all of the cases but there were few adhesions over the rest of the lung. There was little hilar involvement and dissection was accomplished with relative ease. Only one case offered a technical problem. A large cavity 10 by 4 by 3 cm. was found to have crossed the interlobar fissure so as to involve the posterior portion of the right upper lobe as well as the entire dorsal division of the right lower lobe. In this case the right lower lobe was removed along with a segment of the right upper lobe.

PATHOLOGY

The granulomatous lesions were removed from the left upper lobe in three cases and from the right lower lobe in the remaining case. The pathogenic organism was seen microscopically in three of the lesions and cultured from the fourth. The nodules varied from 2 to 4 cm. in diameter. Two of the four lesions were solid. One had a liquified center and the other showed a central area of cavitation which communicated with a bronchus (Figs. 8 and 9). In a typical granuloma there is caseation toward the center with a very gradual change to an area where the caseation is intermingled with a fibrous stroma. This area usually contains recognizable alveoli and occasional giant cells. Near the periphery of the lesion the fibrous element becomes more dense and some hyalinization is present. Occasional giant cells are also seen in this area. Normal lung with little distortion usually surrounds the lesion but sometimes the fibrous element extends into the surrounding alveoli. In the case in which there was bronchial communication there was also a surrounding area of chronic interstitial pneumonitis with infiltration of plasma cells, eosinophiles, and lymphocytes, and at some distance from the nodule there was an area of suppurative bronchitis with surrounding pneumonia. Two of the specimens had smaller nodules intimately connected with the larger nodule but in only one were spherules seen in these satellite granulomas.

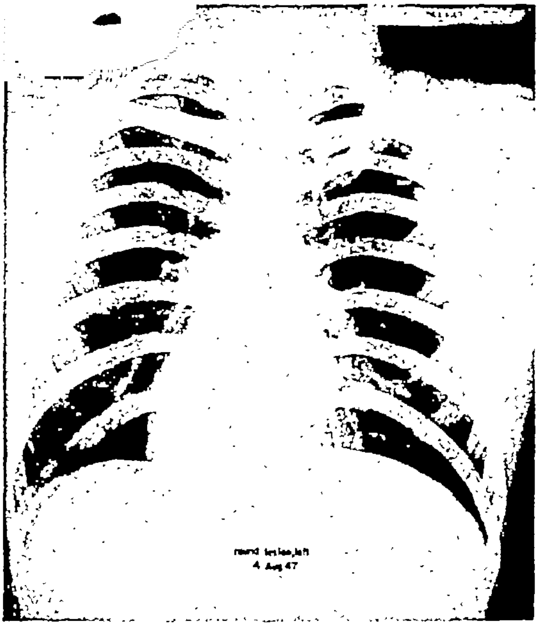

Fig. 8.—Granuloma, left upper lobe.

The cavitation involved the right upper lobe in five cases, the left upper lobe in two, the left lower lobe in two, and the right lower lobe was involved in one patient along with the right upper lobe involvement. At least one form of the pathogenic organism was seen in every case; the mycelial form was observed in six specimens and the spherule form in six. Three of the cavities contained air under pressure and they all contained a small amount of fluid. Satellite nodules were palpable and visible about the cavity or even throughout the involved lobe in all except two cases. The pathology of the cavity is fairly consistent. There is an outer fibrous layer 0.1 to 0.5 cm. thick which makes the area of cavitation feel firm in the intact specimen. The lining appears rough and irregular and is composed of a grayish-yellow caseous layer 0.2 to 0.5 cm. thick. Small areas of granulation tissue with evidence of recent hemorrhage are frequently seen projecting into the cavity. On microscopic examination the lining of the cavity is seen to consist mainly of a surface zone of necrotic tissue with few identifiable cells. Both forms of the fungus are frequently seen clinging to this area. In some cases there are areas of granulation tissue, stratified squamous epithelium, or ciliated stratified squamous epithelium in the lining. This inner layer blends into a necrotic zone in which there is loosely interspersed a fibrous stroma with macrophages and eosinophiles. This is surrounded by a more dense fibrous zone into which protrude fibrous bands, many of which are coarse and collagenous. This zone contains many plasma cells and eosinophiles as well as lymphocytes and occasional giant cells. The fibrous zone extends into surrounding lobules obliterating alveoli. In seven of the nine cases there were satellite lesions consisting mainly of tubercles formed by epithelioid cells or epithelioid cells surrounding giant cells and spherules were seen in these lesions in two of the specimens. There were also areas of chronic pneumonitis, caseous lobular pneumonia, and caseation necrosis surrounding the cavities.

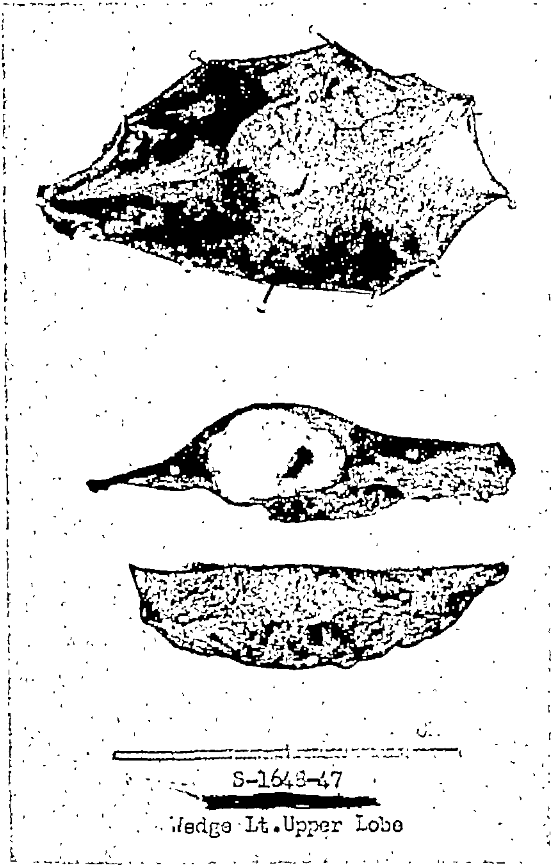

FIG. 9.—Excised granuloma with central area of cavitation which communicated with a bronchus.

Most of these lesions were near the cavity but sometimes they were found a considerable distance away. It is interesting to note that a single regional lymph node was involved in only one case, although next to the lung this is the most commonly involved site in disseminated cases.

POSTOPERATIVE COURSE

The postoperative course of the segmental resections was uneventful in every case. There were no complications. The nine patients having lobectomies had much the same course as would be expected in a similar group with bronchiectasis. There was no incidence of bronchopleural fistula or empyema. One patient developed diffuse mottling throughout the opposite lung on the day following lobectomy. This process increased in the next few days but was not accompanied by any toxicity. Only a small amount of sputum was obtained when the patient was bronchoscoped and no *C. immitis* colonies grew when this material was cultured. Since dissemination was feared, a specimen of blood was sent for serological examination.* Both the precipitin and complement fixation tests were negative. The lesions cleared progressively and were entirely absent two months after surgery. He was well one year after surgery.

SUMMARY OF RESULTS

The four cases having wedge resection of granulomatous lesions have been observed for an average of fourteen months following surgery. The first patient was operated upon thirty-five months ago and the last case only four months ago. None of them had symptoms other than pain near the site of operation. They are all at work and there has been no evidence of any other lesion on postoperative roentgenograms.

The nine cases having lobectomy for coccidioidomycosis with cavitation have been followed an average of eighteen months after surgery. The first operation was done thirty-two months ago and the last was three months ago. All patients have been contacted recently except one whose address has been lost; he was last seen twenty months after surgery at which time he was well. Six of the nine patients have been benefited by the surgery in that their symptoms have been markedly improved or abolished and there is no evidence of active disease in the remaining lung tissue. These six men are all working full time. Another patient still has troublesome symptoms. He is able to work full time doing light delivery work but he tires easily. The last x-ray picture taken at Fitzsimons General Hospital six months ago showed no evidence of any pulmonary lesion. Two of the patients are now in worse condition than they were prior to surgery. One of these patients developed pulmonary tuberculosis with cavitation in the right lower lobe three months after resection of the right upper lobe. Before surgery tuberculin skin tests were negative in first and second strengths and the sputum had been negative for acid-fast bacilli on twenty-one smears, ten cultures, and two guinea pig inoculations. The pathologic examination of the excised lung revealed the typical lesion of coccidioidomycosis with large numbers of spherules visible in the cavity, in the walls of the cavity, and in the satellite granulomas. There was no evidence of tuberculosis. There was a patent bronchus communicating with the cavity. The patient has been hospitalized fourteen months for the tuberculosis and the sputum has been negative for acid-fast bacilli for eight months, but there is still a question of cavitation in the right lower lobe. The other patient had severe symptoms and was definitely suffering from a chronic and debilitating disease at the time of surgery. He had almost immediate relief from the symptoms and gained weight rapidly following resection of the right upper lobe. He was asymptomatic for two years, but suddenly the symptoms returned, and he is now almost as ill as before operation. He has a 3 cm. cavity in the right lower lobe, and the sputum is again positive for *C. immitis* (see Case 2).

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*By Dr. C. E. Smith.

DISCUSSION

The management of chronic granulomatous lesions of coccidioidomycosis appears to be simple. The diagnosis can seldom be made with certainty and it is a sound policy to remove these tumors for no other reason than to establish a diagnosis and rule out the possibility of a more dangerous lesion. Even if the diagnosis is without question, it seems that the threat of cavitation or dissemination should be abolished while the lesion is in a more focalized form. Even though dissemination from these foci must be an unusual occurrence, the operative removal is relatively simple and seems to be the safer course.

The problem of dealing with persistent cavitation is a difficult one. Most of these lesions do not produce symptoms or debilitation and patients with cavitation have been known to do hard work for years with no apparent ill effect. However, even when no symptoms exist, these cavities should not be regarded as innocuous. They are usually near the periphery of the lung and in four cases presented in a previous paper they have ruptured causing bronchopleural fistula, coccidioidal empyema, and nonexpansile lung.[9] There is also evidence that these foci of infection may be a source of dissemination, although there is little likelihood of this taking place long after the initial infection. From the standpoint of epidemiology there has been no record of a proved direct human transmission of the disease and for this reason patients with open cavities are not isolated. However, the reason commonly proposed for the lack of human transmission has been that the spherule form of the organism, which is usually seen in the sputum, exudates, and diseased tissue of infected patients has a low infectivity, while the highly infectious mycelial form grows only in an external environment. It is to be noted that six of the cavities removed contained mycelial forms. Either the disease will be transmitted when individuals with open cavities return to their families outside of endemic areas or there is some other factor in the transmission of the disease. In spite of these possible complications, our expérience in the management of this small group of nine cases suggests that pulmonary resection should be reserved for those patients having definite symptoms over a long period of time. In the few cases presenting incapacitating symptoms and evidence of chronic debilitating disease after prolonged hospitalization, pulmonary resection is indicated. It may be that a longer period of hospitalization before and after surgery would be beneficial.

CONCLUSIONS

1. Four patients with focalized granulomatous lesions have been treated satisfactorily by wedge resection of the diseased portion of lung. We feel that these lesions should be removed in order to rid the patient of a possible source of dissemination and in order to rule out the possibility of a more malignant process which might have an identical roentgenologic appearance.

2. Coccidioidal cavities have been removed by lobectomy in nine cases. Lobectomy should be reserved for those patients who have distressing symptoms over a period of many months.

REFERENCES

1. Smith, C. E.: Coccidioidomycosis, M. Clin. North America 27: 790, 1943.
2. Smith, C. E., Beard, R. R., Whiting, E. G., and Roseberger, H. C.: Varieties of Coccidioidal Infection in Relation to Epidemiology and Control of the Disease; Am. J. Pub. Health 36: 1394, 1946.
3. Willett, F. M., and Weiss, A.: Coccidioidomycosis in Southern California; Report of a New Endemic Area With a Review of 100 Cases, Ann. Int. Med. 23: 349, 1945.
4. Goldstein, D. M., and McDonald, J. B.: Primary Coccidioidomycosis, Pulmonary (Follow-up of 75 cases With Ten Cases From a New Endemic Area), J. A. M. A. 124: 557, 1944.
5. Forbus, W. D.: Coccidioidomycosis: A Study of 95 Cases of the Disseminated Type With Special Reference to the Pathogenesis of the Disease, Mil. Surgeon 99: 653, 1946.
6. Winn, W. A.: Pulmonary Cavitation Associated With Coccidioidal Infection, Arch. Int. Med. 68:1174, 1941.
7. Winn, W. A.: Treatment of Pulmonary Cavitation Due to Coccidioidal Infection, California & West. Med. 57: 45, 1942.
8. Rakofsky, M., and Knickerbocker, T. W.: Roentgenological Manifestations of Primary Pulmonary Coccidioidomycosis, Am. J. Roentgenol. 56: 141, 1946.
9. Greer, S. J., and Grow, J. B.: The Surgical Lesions of Pulmonary Coccidioidomycosis, Dis. of Chest 16: 336, 1949.

DISCUSSION

DR. DONALD L. PAULSON, Dallas.—(Slide.) This patient was admitted to the hospital in April, 1945, because of hemoptysis. Roentgenograms revealed a thin-walled cavity in the right upper lobe. While he was under observation the cavity ruptured into the pleural cavity, resulting in a pneumothorax with fluid. This was aspirated and *C. immitis* was found in the fluid. A diagnosis of coccidioidomycosis of the lung and pleura was made. Attempts to expand the lung were not successful and a decortication was done. A thickened fibroblastic membrane was found overlying the lung and the parietal pleura. This membrane was removed, and a segmental resection of the posterior segment of the right upper lobe was done to remove the cavity. The organisms of coccidioidomycosis were found in the fibroblastic membrane.

The patient had an uneventful convalescence following this surgery. He has had no further symptoms and is now leading a normal life. The second slide shows a roentgenogram made in 1948 which reveals complete expansion of the lung with no evidence of residual disease.

DR. FORRESTER RAINE, Milwaukee.—I am rather surprised that in these cavities which were treated by resection, only three were found in which the mycelium was growing on the walls. Most patients with coccidioidomycosis recover without difficulty, but we had one similar to these in which mycelium was growing on and in the wall of the cavity. This, I think, accounts for the very copious sputum as well as repeated hemoptysis which is not seen in the granulomas containing the endospore form of the fungus.

These slides show a patient operated upon by Dr. Wilson Weisel at the Veterans' Hospital in Milwaukee. The first slide shows the cavity small in 1945, the next larger in

1946, and the next several times larger by 1947. A lobectomy was performed in 1948 and the final slide shows the specimen with the large cavity and possibly you can see the roughness of the wall where pure culture of the mycelium was obtained.

DR. ROBERT R. SHAW, Dallas.—The increasing awareness of this disease in our part of the country has posed a difficult problem in the differential diagnosis of tumors within the lung. There is a prevalence of skin testing for both the coccidiodes or/and histoplasmosis. Sometimes the internist or the physician carrying out the skin testing is quite satisfied with the positive reaction in explaining the presence of a shadow within the lung field. In two patients with carcinoma in the past two years this has led to a too-long period of waiting with the result of inoperability by the time the true diagnosis was made. So here again, as with virus pneumonia and unresolved pneumonia, we must be very circumspect in explaining shadows that appear in the lung fields on the basis of a nonspecific skin test.

I want to show a specimen of a left upper lobe that was removed as a result of a shadow found in a survey. This subsequently proved to be a coccidioidal granuloma with daughter granulomas within the same lobe. I think these lesions should be removed for their own presence, regardless of the fact that they may be found because of a suspected diagnosis of carcinoma. This man denied having symptoms at the time the survey was taken, he was a food handler—but after the lobectomy had been completed and within a month following removal of this lobe, he volunteered the information that he felt entirely different now than he did before surgery. He had a feeling of well-being now that he had not had before. This man had been present in an endemic area for only approximately six months, during which time he was visiting in El Paso. We do not consider coccidioidal mycosis to be endemic in the regions of Central Texas, but we must be continually on the alert for this condition. The coccidioidal granuloma is, of course, very similar to the tuberculoma and if an accurate diagnosis can be made I think it becomes difficult to advise the patient just what should be done, if he denies having any symptoms whatsoever. I am of the opinion, however, that even with a proved diagnosis these granulomas should be removed.

DR. W. L. ROGERS, San Francisco.—Until recent years we in California and the Southwest had a monopoly on this interesting clinical entity. I think it is quite obvious to all of us here that that condition no longer exists. I believe this excellent review is quite timely, and it is my belief that this is the first occasion this condition has been presented before this surgical association. I would like to confine my few words to the latent residual cavity. In our experience that has been the most frequent of the late complicating conditions with which the clinician is confronted. To give you briefly an idea of what the average clinician in our area may expect in the ordinary course of these residual cavities, let us consider a theoretical 100 cases. We may assume that sooner or later approximately 40 per cent of this group will close spontaneously. Approximately 20 per cent will remain relatively symptom-free. The remaining 40 per cent will require active therapy either because of increasing size or because of recurrent severe hemoptysis. I might say at this time approximately 70 per cent of these residual cavities at one time or another will give a history of small hemoptysis and approximately 10 per cent also will give a history of secondary infection. We feel a trial by conservative collapse measures, such as pneumothorax or pneumoperitoneum, should be afforded this group. Pneumoperitoneum may be occasionally supplemented by a temporary phrenic if that seems necessary. Collapse measures are effective in approximately 90 per cent of this residual group. Collapse therapy should be maintained for about one year. The remaining 10 per cent obviously should come under surgical consideration.

In closing I should like to mention two other points. If one is not familiar with this disease, particularly so far as laboratory work is concerned, we must be very careful, indeed, to warn laboratory technicians of the possible danger involved. In Dr. Smith's laboratory at Stanford, no technician is employed who does not have a positive coccidiodin. On one occasion a visiting physician merely passing through the laboratory contracted the disease. In San Francisco, because of the availability of Dr. Smith's laboratory, our other private institutions prefer not to handle these cultures at all.

Also, I would like to ask Colonel Forsee or Dr. Greer their feeling regarding the granting of 100 per cent permanent disability rating to these veterans who have been subjected to lobectomy irrespective of how well they may do clinically. This appears to me to be an injustice, especially when the operation is performed for a curable disease.

DR. O. A. ABBOTT, *Atlanta.*—I hesitate to go on with this discussion, but we did encounter a very interesting and rather unusual complication of this disease at our local Veterans Facility. The patient was a physician's son, 24 years of age, and had an acute coccidioidal pneumonitis four years before when stationed in San Joachin Valley territory. The pulmonary lesion cleared completely, and then he developed typical signs of constrictive pericarditis, and he was considered for surgery. The sedimentation rate was extremely high and the skin tests for coccidiodomycin very strong, also the skin test for tuberculin was very strong. We thought it important to utilize the additional safety precaution of giving the patient streptomycin because of the reports of the possible value of this drug in coccidioidomycosis. This was done and in one month's time the sedimentation rate was normal, and a pericardiectomy was performed. The pericardium contained the typical spherules but no mycelia were seen. There has been no evidence of recurrence of the lesion since this surgery.

COL. FORSEE.—I wish to thank the members of the Association who have discussed this paper and presented questions in which we are very much interested. There were six of the cases with cavitary lesions that had mycelial forms present, rather than three. The surgical therapy which has been carried out in these cases seems to be the best we have available at the present time; however, it leaves much to be desired. Follow-up letters that we have received from all of these patients indicate a degree of residual chronicity of the disease somewhat out of proportion to that usually seen after such operative procedures. It has been our practice to have these patients hospitalized for prolonged periods before they are operated upon. We now wonder, particularly since this one patient has returned with a cavity in the remaining lung tissue, if it would not be desirable to treat these patients with prolonged bed rest after surgery, particularly those having cavitary lesions.

In the excision of granulomatous lesions, just one word of warning, that is, that there should be a wide resection with normal lung tissue excised because of the danger of adjacent granulomatous daughter involvement about the original granuloma.

We have no answer to the problem of disability following lobectomy. We have returned several of these patients to duty following lobectomy, and that is our practice at the present time. In a simple, uncomplicated lobectomy for other than neoplastic or tuberculous disease our policy is to return the soldier to general military duty. Whether or not we are correct in this we do not know, and we would be very much interested to know what the Veterans Administration does in the matter of disability. I am sorry I cannot answer your question, Dr. Rogers, except to say that we have felt that the mere absence of a lobe of a lung certainly does not constitute a disability for which the individual should receive retirement pay or pension benefits for the remainder of his life.

BLOOD VOLUME AND EXTRACELLULAR FLUID CHANGES DURING THORACIC OPERATIONS

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THE first measurements of the amount of blood lost during operations were made by Gatch and Little[1] in 1924. Blood loss was estimated by determining colorimetrically the acid hematin concentration in the washings of blood-soiled sponges and instruments. The authors pointed out that blood loss was often greatly in excess of the surgeon's estimate. Losses of 500 to 700 c.c. were well tolerated by individuals in good physical condition, while losses greater than 1,000 c.c. were usually accompanied by serious effects. Additional colorimetric studies of blood loss during major abdominal operations have substantiated these observations.[2, 3] White and Buxton[4] using the same method found an average blood loss of 700 c.c. for thoracoplasty stages and 1,500 c.c. for lobectomy. Nadal measured blood loss during orthopedic operations,[5] and blood loss during neurosurgical procedures was studied by White and associates.[6] The colorimetric method yielded figures which were 1 to 7 per cent[3] and 13 to 14.6 per cent[4] below the actual values when a known quantity of blood was washed from soiled sponges or linen. Shock did not become clinically evident until the patient had lost 20 per cent of the normal blood volume or approximately 1,200 c.c. Patients losing less than 20 per cent of their normal blood volume were not likely to develop clinical evidence of shock unless the loss had been rapid. These authors urged immediate replacement of blood during operation and warned against delay until shock had become evident.

Wangensteen,[7] in 1942, described a gravimetric method for estimating blood loss during operation. Blood loss was measured by determining the difference in weight between dry gauze sponges before and immediately after use. By this means the surgeon can have an accurate estimate of blood loss at any time during the operation. Baronofsky, Treolar, and Wangensteen,[8] using both the colorimetric and gravimetric methods, found an average blood loss of 1,324 c.c. for lobectomy and 1,534 c.c. for pneumonectomy; values obtained with the gravimetric method were 10 per cent higher than values obtained with the colorimetric method.

Gibbon, Gibbon, and Kraul[9] have demonstrated that a blood transfusion of a size well tolerated by normal animals may produce pulmonary edema in cats in which there has been an acute reduction of pulmonary tissue. Thornton and associates[10] have demonstrated the role of the rate of administration of massive transfusions after pulmonary resection in the development of pulmonary edema in dogs. Over-replacement with blood, either during or imme-

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diately after lobectomy or pneumonectomy in man, may tend to precipitate pulmonary edema. On the other hand, inadequate replacement of blood lost may lead to surgical shock. Changes in the pulse rate and blood pressure are not reliable signs of blood loss, especially in the older, poor-risk patient. It is obviously desirable to maintain a normal circulating blood volume at all times during a major operation. This can be accomplished only by transfusing blood during the surgical procedure at the same rate that it is lost in the operative wound.

Coller, Crook, and Iob,[3] Stewart and Rourke,[11] and McAllister[12] have shown that postoperative changes in the hematocrit, hemoglobin, and plasma protein are not necessarily related to changes in the blood and plasma volumes and consequently cannot be used to determine blood loss. The amount of blood and fluid lost must, of necessity, be based on direct measurement.

Sponge Weight Method.—Dry sponge technique[7] was employed during the entire surgical procedure. A weighing scale of 0.1 Gm. sensitivity was used. All sponges and aspiration bottles were weighed immediately before operation. They were weighed again, immediately after use, to minimize error resulting from evaporation. The blood loss was calculated from gain in weight of sponges and aspiration bottles. This value was then converted to volume of blood in cubic centimeters by multiplying by 1.055 which was arbitrarily taken to be the average specific gravity of blood.

Dye Method for Determining Blood Volume.—The T-1824 method of Gibson and Evans,[13] adapted for use with the Evelyn colorimeter by Gibson and Evelyn,[14] was used to determine plasma volumes. Ampules* containing a sterile aqueous solution of T-1824 in 0.5 per cent concentration were used. Each batch of dye was standardized before use. Blood volume determinations were performed with the patient in the recumbent position. Postoperative determinations were made within forty-five minutes after conclusion of the operation. The quantity of dye used varied with the size of an individual. Large quantities of dye may produce objectionable discoloration of the skin, especially in patients having small plasma volumes. Little, if any, discoloration of the skin results from a dose of 0.25 mg. per kilogram of body weight.

Syringes and needles used for injection of the dye were volumetrically calibrated for delivery by determining the weight of distilled water delivered. Syringes were filled with distilled water to the point where marks on both the plunger and barrel coincided. The water was then expelled through a dry needle into a weighing bottle. Recalibrations were performed at intervals to assure continued accuracy. Using calibrated syringes, the difference between repeated determinations, done within a twenty-four hour period, in twenty-five instances lay between 0.4 and 7.0 per cent. The mean experimental difference in repeat determinations in patients was 4.0 per cent. The standard error of estimation was ±176 c.c.[15]

The dye was injected within a period of five seconds into a large vein of the forearm by means of the calibrated syringe. The syringe was not flushed with blood. The site of puncture was firmly compressed after withdrawal of the needle in order to prevent extravasation of the dye. The first blood sample was obtained from the vein of the opposite arm seven and one-half minutes after the beginning of the dye injection. Four or five additional blood samples were obtained at two and one-half minute intervals. The blood was permitted to clot and clear serum obtained by centrifugation at 2,000 R.P.M. for fifteen minutes. Obviously hemolyzed serum samples were discarded. The optical density of the dye was measured with the Evelyn photomicrocolorimeter at a wave length of 620 mμ. Any slight hemolysis was detected by measurement at 540 mμ,[15] and the light transmission at 620 corrected by this value. The correction was usually insignificant. The corrected values of optical density of T-1824 were then plotted against time and the optical density at zero time found by extrapolation. All plasma volumes were calculated from the extrapolated optical density. Blood volumes were calculated from the plasma volumes and the hematocrit. Plasma protein concentrations were obtained by the copper sulfate method.[16]

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*Obtained from William R. Warner & Company, New York, N. Y.

Cruickshank[17] has shown a marked difference in the slope of the excretion curve of T-1824 in repeated determinations. The mixing time of the dye is also prolonged in shock.[18] Because of the possibility of changes in the mixing time and the excretion rate of the dye, in the immediate postoperative period, we have attempted to minimize the error of the method by employing the extrapolated values of the optical density instead of using that measured in a single ten minute sample. Furthermore, we have found that the plasma volume calculated from the optical density of the dye in a single ten minute sample may be between 0.5 and 3.0 per cent higher than that calculated from the optical density of the dye extrapolated to zero time. Blood volume measurements using isotopic iron have been consistently lower than those obtained with the dye method.[19]

Blood lost during the operation was computed by subtracting the postoperative blood volume from the preoperative blood volume and adding the amount of blood transfused during operation. In most instances the exact amount of blood transfused during operation was determined by weighing the transfusion bottles before and after use. The amount of 5 per cent glucose in water given during operation was also measured by weighing the containers before and after use.

Sodium Thiocyanate Method for Determining Extracellular Fluid.—The fluid available for the dilution of sodium thiocyanate, hereafter referred to as the extracellular fluid, was determined both preoperatively and postoperatively as ferric thiocyanate according to the method of Crandall and Anderson.[20] Syringes used for the injection of sodium thiocyanate were volumetrically calibrated to the tip by determining the weight of distilled water contained. An average of 15 mg. per kilogram of sterile 5 per cent sodium thiocyanate solution* was injected intravenously approximately thirty minutes prior to the injection of T-1824. The syringe was then flushed three times with blood to insure complete delivery. Blood samples for thiocyanate determination were obtained thirty minutes after injection, at which time diffusion equilibrium is usually attained.[11, 20, 21] The dye T-1824 was then injected through the same needle immediately after withdrawal of the thirty minute blood sample for thiocyanate determination. Additional thiocyanate determinations were made from blood samples withdrawn for plasma volume determinations. The dye is completely precipitated during the preparation of the protein-free filtrate and consequently does not interfere with the measurement of thiocyanate concentration.[22] The thiocyanate concentration in each sample, measured as ferric thiocyanate with the Klett-Summerson colorimeter, was then plotted against time. Calculations of extracellular fluid were based on the thiocyanate concentration at the point where excretion assumes a constant value. In many instances the concentration continued to decline at a steady rate. The calculation of extracellular fluid in these instances was based on the concentration of the thirty minute sample.

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*Obtained from William H. Rorer, Inc., Philadelphia, Pa.

The mean experimental difference between repeat determinations within seventy-two hours in six patients was 3.3 per cent with a minimum and maximum difference of 1.0 and 5.8 per cent. The standard error of estimation was ±337 c.c.

OBSERVATIONS

Plasma volume was determined by using the blue dye T-1824 both preoperatively and postoperatively in a series of fifty-seven patients subjected to major thoracic operations. Blood volume was calculated from the plasma volume and the hematocrit. The extracellular fluid volume was measured with sodium thiocyanate both preoperatively and postoperatively in thirty-three patients in this series. Blood loss during operation was measured by the sponge weight method in twenty-seven instances.

Comparison Between the Sponge Weight Method and Dye Method for Determining Blood Loss.—Both methods for measuring blood loss were used in twenty-seven major thoracic operations (Fig. 1). In twenty-one instances the blood loss by the dye method was greater than the loss estimated by the sponge weight method. In general, the difference between the two methods was not marked. The greatest differences were 592 and 434 c.c. in Cases 19 and 14, respectively.

Thoracoplasty.—Postoperative blood volume changes were studied in ten patients subjected to first stage thoracoplasty (Table I). The extracellular

TABLE I. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING FIRST STAGE THORACOPLASTY (TEN CASES)

	BLOOD LOST* (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID LOSS 5 CASES (C.C.)
Minimum	406	340	252
Maximum	1885	575	2840
Average	734	475	1352

*The figures for "blood lost" were derived from blood volume determinations in this and in subsequent tables.

fluid volume was studied in five of these patients. Blood loss during operation was gravimetrically measured in four instances. The average operative time was two hours, sixteen minutes. Continuous spinal anesthesia was used in all cases.

The maximum postoperative blood volume deficiency was 1385 c.c. or 23.5 per cent of the preoperative blood volume, though clinical evidence of shock did not occur. A postoperative increase in hematocrit values was observed when blood loss had been adequately replaced. A decrease was observed when blood loss had been inadequately replaced with the exception of one patient. All patients were deficient in extracellular fluid volume postoperatively.

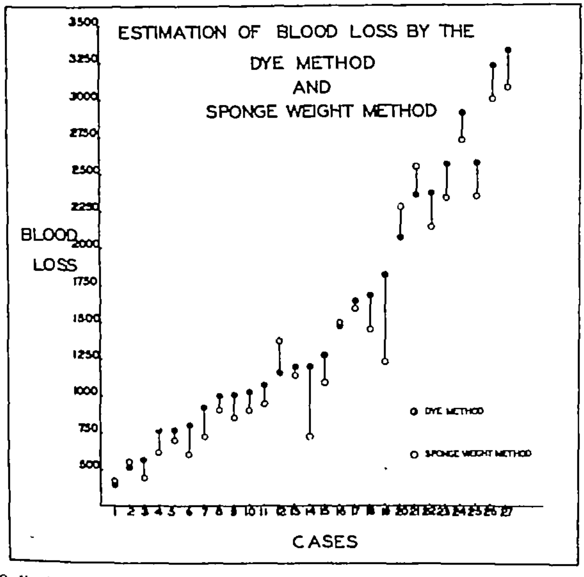

Fig. 1.—Ordinates represent blood loss in cubic centimeters. The twenty-seven cases are arranged in the order of increasing blood loss.

Thoracotomy.—Postoperative blood volume changes were studied in eleven patients subjected to thoracotomy (Table II). Six patients had inoperable carcinoma of the lung, three had inoperable carcinoma of the esophagus, and two had extrapulmonary tumors removed. The extracellular fluid volume was studied in seven of these patients. Blood loss during operation was measured by the sponge weight method in seven instances. The average operative time was two hours. Endotracheal ether anesthesia was used in all instances.

The maximum postoperative blood volume deficiency was 504 c.c., or 10.3 per cent of the preoperative blood volume. Clinical evidence of shock did not

TABLE II. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING THORACOTOMY (ELEVEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 6 CASES (C.C.)	LOSS 1 CASE (C.C.)
Minimum	364	500	115	122
Maximum	1679	1980	1323	
Average	1074	977	+559	

develop in any of these patients. A postoperative increase in the hematocrit value was noted when the blood lost was adequately or more than adequately replaced, although no quantitative relationship existed. A decrease in the hematocrit value was observed when the blood lost was inadequately replaced, except in two instances. Postoperatively, no patients showed a significant loss in extracellular fluid volume.

Partial Lung Resection.—Postoperative blood volume changes were studied in thirteen patients subjected to lobectomy for bronchiectasis. The extracellular fluid volume was studied in nine of these patients. Blood loss during operation was measured by the sponge weight method in seven instances. The average operative period was three hours, fifty-one minutes. Endotracheal ether anesthesia was used in all cases (Table III).

TABLE III. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING LOBECTOMY (THIRTEEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 2 CASES (C.C.)	LOSS 7 CASES (C.C.)
Minimum	700	1066	107	499
Maximum	2919	2723	125	3860
Average	1778	1771	−1110	

The maximum postoperative blood volume deficiency was 857 c.c., or 22 per cent of the preoperative blood volume. This patient showed clinical evidence of shock. A postoperative increase in the hematocrit value was observed in patients with adequate and excessive blood replacement. No quantitative relationship between the hematocrit and degree of over-replacement existed. Postoperatively, a decrease in the hematocrit was observed in cases with inadequate replacement except in two instances. There was a significant decrease in the extracellular fluid volume in five of the nine patients studied.

Esophagectomy.—Postoperative blood volume changes were studied in seven patients subjected to esophagectomy for lesions involving the thoracic esophagus. In six instances esophagectomy was performed for carcinoma and once for esophageal stricture. The extracellular fluid volume was studied in three of these patients. The average operative time was five hours, twenty-nine minutes. Endotracheal ether anesthesia was used in all cases (Table V).

TABLE IV. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING PNEUMONECTOMY (SIXTEEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 1 CASE (C.C.)	LOSS 7 CASES (C.C.)
Minimum	684	850	522	408
Maximum	3597	3658		2361
Average	1915	1954	-1158	

TABLE V. BLOOD AND EXTRACELLULAR FLUID CHANGES DURING ESOPHAGECTOMY (SEVEN CASES)

	BLOOD LOST (C.C.)	BLOOD GIVEN (C.C.)	POSTOPERATIVE EXTRACELLULAR FLUID	
			GAIN 2 CASES (C.C.)	LOSS 1 CASE (C.C.)
Minimum	1284	1000	88	1888
Maximum	2570	3000	1278	
Average	1870	2228		

The maximum postoperative increase in blood volume was 839 c.c. This represents an increase of 17.8 per cent of the preoperative blood volume. This patient did not develop any postoperative respiratory or circulatory complications. Postoperative increase in the hematocrit was observed in all cases of adequate and over-replacement. A decrease in the hematocrit was observed in the one patient in whom blood loss was inadequately replaced. One patient showed a significant deficiency in extracellular fluid volume postoperatively. There was a postoperative gain in extracellular fluid in the other two patients. In both these patients there was a more than adequate replacement of blood and fluid.

Total Lung Resection.—Postoperative blood volume changes were studied in sixteen patients subjected to pneumonectomy. Pneumonectomy was performed in thirteen of these patients for carcinoma, and in three for bronchiectasis. Changes in the state of hydration were studied in eight of these patients. Blood loss during operation was gravimetrically measured in six instances. The average operative time was three hours, fifty-seven minutes. Endotracheal ether anesthesia was used in all cases (Table IV).

The maximum postoperative blood volume deficiency was 878 c.c. This represents a deficiency of 16.3 per cent of the preoperative blood volume. Clinical evidence of shock was not observed in any patient. In one instance, the postoperative blood volume was 732 c.c., or 17.4 per cent greater than the preoperative value. This patient did not develop any postoperative respiratory or circulatory complications. Postoperatively, the change in the hematocrit values could not be correlated with changes in the blood volume.

In eight determinations of the extracellular fluid volume, only one patient showed a gain of 522 c.c. In this instance there was over-replacement of both

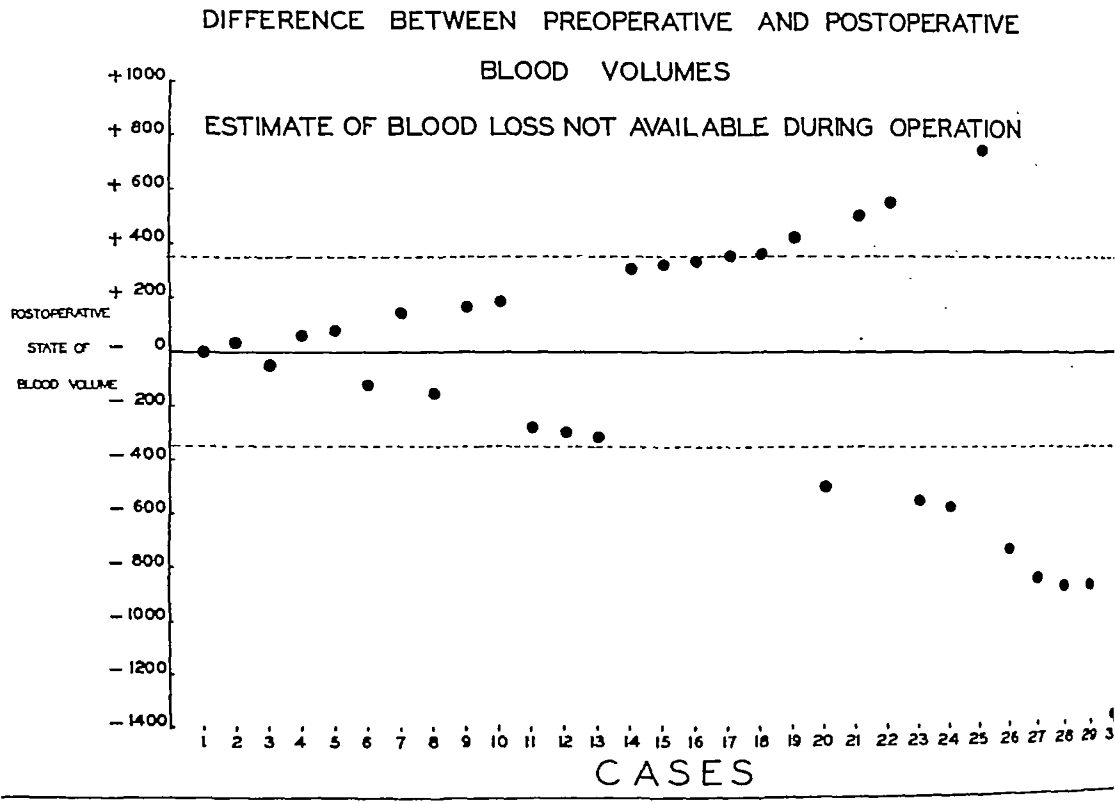

Fig. 2.—Ordinates represent increase, or decrease, in postoperative blood volume in cubic centimeters. Sponge weight method was not used.

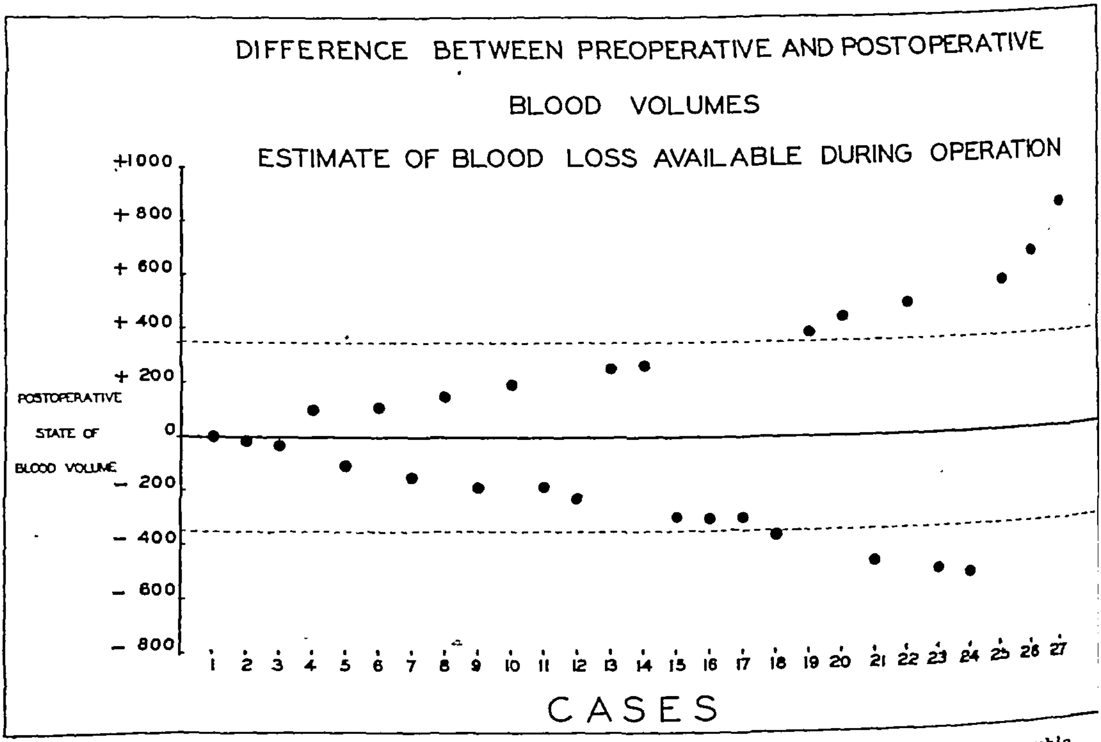

Fig. 3.—Ordinates represent increase, or decrease, in postoperative blood volume in cubic centimeters. Sponge weight method was used.

blood and fluid during a short operation. There were significant decreases in the extracellular fluid in the other seven patients.

Blood Replacement Controlled by Gravimetric Estimate of Blood Loss.— In thirty of the fifty-seven patients studied, the sponge weight method of estimating blood loss was not used. In this group the blood loss was significantly over-replaced in six patients and significantly under-replaced in eight patients (Fig. 2). The maximum postoperative blood volume deficiency in this group was 1,385 c.c.

In the remaining twenty-seven patients an estimate of blood loss by the sponge weight method was available *during* the operation. In this group the blood loss was significantly over-replaced in six patients and significantly under-replaced in four patients (Fig. 3). The maximum postoperative blood volume deficiency in this group was 540 c.c. It would appear that when an estimate of the blood loss is available during the operation, a normal blood volume can be more easily maintained and serious under-replacement of blood avoided.

DISCUSSION

The average values for blood loss during major thoracic operations presented in this paper are in general agreement with those reported by others. The blood loss computed by the dye method is believed to be more indicative of the actual blood loss, since small quantities of blood may escape detection by the sponge weight method. The dye method generally gave higher values for blood loss than the sponge weight method. This may be related to the blood and plasma loss into the wound and pleural cavity postoperatively and prior to the blood volume determination. Thomas, Adams, and Thornton[23] have shown that the hemoglobin concentration and red blood cell count decrease steadily during the postoperative period, reaching the lowest level from the third to the eighth day.

Coller and Maddock[24] investigated dehydration during surgical operations by weighing the patient preoperatively and postoperatively. Water loss varied between 97 and 705 Gm. during uncomplicated procedures. When one considers the large surface area exposed in an open pleural cavity, losses of large quantities of water by evaporation are to be expected. The large surface exposed during thoracoplasty, especially in first stage procedures, may account for the fluid loss in these patients. Shorter operative procedures such as exploratory thoracotomy are not accompanied by large fluid loss. In fact, most of these patients showed a gain in extracellular fluid postoperatively. A postoperative increase in the extracellular fluid has previously been observed by Stewart and Rourke[11] which they attributed to ether anesthesia. Cope and Moore[25] have recently reported gains in extracellular fluid as great as 50 per cent in seriously burned patients. McAllister[12] noted an average decrease of 11 per cent in the plasma volume of experimental animals after ether anesthesia.

SUMMARY

1. Blood volume was measured by the dye method before, and immediately following, fifty-seven major thoracic operations.

2. In twenty-seven of these fifty-seven patients the blood lost at operation was estimated by weighing gauze sponges before and after use in the operative field.

3. The blood lost during operation was more accurately replaced by transfusion when the sponge weight method was used.

4. Significant losses of extracellular fluid usually occurred during long operations.

CONCLUSION

In major thoracic operations it is important to measure blood loss by observing the increase in weight of the gauze sponges used. At present this is the only method which gives a continuous record of the blood lost during the course of an operation, and hence, permits simultaneous accurate replacement by blood transfusions.

The technical assistance of Mr. Franz Goldstein and Miss Theresa D'Urso is gratefully acknowledged.

REFERENCES

1. Gatch, W. O., and Little, W. D.: Amount of Blood Loss During Some of the More Common Operations, J. A. M. A. 85: 1075, 1924.
2. Oppenheim, A., Pack, G. T., Abels, J. C., and Rhoads, C. P.: Estimation and Significance of Blood Loss During Gastro-Intestinal Surgery, Ann. Surg. 119: 865, 1944.
3. Coller, F. A., Crook, C. E., and Iob, V.: Blood Loss in Surgical Operations, J. A. M. A. 126: 1, 1944.
4. White, M. L., and Buxton, R. W.: Blood Loss in Thoracic Operations, J. THORACIC SURG. 12: 198, 1942.
5. Nadal, J. W.: Blood Loss in Orthopedic Operations, Univ. Hosp. Bull., Ann Arbor, 5: 74, 1939.
6. White, J. C., Whitlow, G. P., Sweet, W. H., and Hurwitt, E. S.: Blood Loss During Neurosurgical Operations, Ann. Surg. 107: 287, 1938.
7. Wangensteen, O. H.: The Controlled Administration of Fluid to Surgical Patients, Minnesota Med. 25: 783, 1942.
8. Baronfsky, I. D., Treolar, A. E., and Wangensteen, O. H.: Blood Loss in Operations, Statistical Comparison of Losses as Determined by Gravimetric and Colorimetric Methods, Surgery 20: 761, 1946.
9. Gibbon, J. H., Gibbon, M. H., and Kraul, C. W.: Experimental Pulmonary Edema Following Lobectomy and Blood Transfusions, J. THORACIC SURG. 12: 60, 1942.
10. Thornton, T. F., Adams, W. E., Bryant, J. E., and Carlton, L. M.: The Use of Whole Blood Transfusions in Resections of the Lung, J. THORACIC SURG. 14: 176, 1945.
11. Stewart, J. J., and Rourke, G. M.: Changes in Blood and Interstitial Fluid, Resulting From Surgical Operations and Ether Anesthesia, J. Clin. Investigation 17: 413, 1938.
12. McAllister, F. F.: The Effect of Ether Anesthesia Upon the Plasma Volume of Dogs, Am. J. Physiol. 119: 363, 1937.
13. Gibson, J. H., and Evans, W. A.: Clinical Studies of Blood Volume; Clinical Application of a Method Employing the Azo Dye Evans Blue and a Spectrophotometer, J. Clin. Investigation 16: 301, 1937.
14. Gibson, J. G., and Evelyn, K. A.: Clinical Studies of the Blood Volume IV; Adaptation of the Method to the Photomicrocolorimeter, J. Clin. Investigation 17: 153, 1938.
15. Snedecor, G. W.: Statistical Methods, Ames, Iowa, 1946, Iowa State College Press, Collegiate Press, Inc.
16. Phillips, R. A. and VanSlyke, D. D.: Copper Sulfate Method for Measuring Specific Gravity of Whole Blood and Plasma, Bull. U. S. Army M. Dept. 71: 66, 1943.
17. Cruickshank, E. W. H., and Whitfield, I. S.: The Behavior of T-1824 in Circulating Blood and a Modified Method for the Estimation of Plasma Volume, J. Physiol. 164: 52, 1945.
18. Noble, R. P., and Gregersen, M. I.: Blood Volume in Clinical Shock, Mixing Time and Disappearance Rate of T-1824 in Normal Subjects and in Patients in Shock; Determinations of Plasma Volume in Man From a 10 Minute Sample, J. Clin. Investigation 25: 158, 1946.

19. Hahn, P. F., Ross, J. E., Bale, W. F., Balfour, W. H., and Wipple, G. H.: Red Cell and Plasma Volumes (Circulating and Total) as Determined by Radioactive Iron and by Dye, J. Exper. Med. 75: 221, 1942.
20. Crandall, L. A., and Anderson, M.: Estimation of the State of Hydration of the Body, Am. J. Digest. Dis. & Nutrition 1: 126, 1934.
21. Lavietes, P., Bourdillon, J., and Klinghoffer, K.: Volume of Extracellular Fluids of the Body, J. Clin. Investigation 15: 261, 1936.
22. Gregersen, M. I., and Stewart, J. D.: Simultaneous Determination of the Plasma Volume With T-1824 and the Available Fluid Volume With Sodium Thiocyanate, Am. J. Physiol. 125: 142, 1939.
23. Thomas, L. B., Adams, W. E., and Thornton, T.: Alterations in the Blood Following Intrathoracic Operations, Surgery 20: 38, 1946.
24. Coller, F. A., and Maddock, W. G.: Dehydration Attendant on Surgical Operations, J. A. M. A. 99: 875, 1932.
25. Cope, O., and Moore, F.: The Redistribution of Body Water and the Fluid Therapy of the Burned Patient, Ann. Surg. 126: 110, 1948.

DISCUSSION

DR. GIBBON.—We began this work one year ago because in major intrathoracic operations we found that we were unable to estimate the amount of blood which had been lost, and thus the amount which should be replaced, by observing the pulse rate and the blood pressure. In a number of patients in whom we had inadequately replaced blood, the pulse rate was quite slow and the blood pressure did not fall until just before a rather precipitous drop. We think that great credit should go to Wangensteen for having suggested the simple method of weighing gauze sponges before and after their use and estimating blood loss by that method. So far as we are aware, there is, at present, no other simple method of determining during the course of an operation how much blood has been lost.

We use this method in all our major thoracic procedures. However, there are two other conditions where it may be quite valuable. One is when there has been quite a large sudden blood loss during an operation and the exact quantity to be replaced is uncertain. The other is—we have had no experience with it but we think it might be of use in that condition—in the second stage of thoracolumbar sympathectomies. The blood pressure after an initial fall following the first stage has returned to high levels. In the second stage there may be considerable bleeding, and after removal of the sympathetic chain there may be a precipitous drop in pressure. The question is whether the drop is due to the sympathectomy or to the blood loss. This can be determined easily by weighing the sponges used. The method then may be of considerable help to neurosurgeons in these situations.

BILOBECTOMY—SURGICAL AND ANATOMIC CONSIDERATIONS IN RESECTION OF RIGHT MIDDLE AND LOWER LOBES THROUGH THE INTERMEDIATE BRONCHUS

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THE multisegmental nature of bronchiectasis is coming to be increasingly recognized with accumulating clinical experience and with the more widespread use of complete bilateral bronchography before the institution of surgical treatment. Among 140 cases of bronchiectasis so studied at New Haven Hospital on the thoracic surgical service[1] only 52 appeared to be confined to a single lobe or unilobar segments. The right lower and middle lobes were involved simultaneously in 19 cases, and of these there was no other demonstrable ipsolateral or contralateral involvement in 8. Stated another way, of 58 cases where right lower lobe bronchiectasis was present, the middle lobe was also similarly diseased in 19, or 33 per cent.

It is of practical importance, therefore, to consider an operative technique by which these two lobes can be removed as a single surgical unit through the common intermediate bronchus. The method usually followed is to carry out seriatim lobectomies through the respective lobar bronchi. This technique has the disadvantage of leaving a long intermediate bronchus with two end stumps, and of requiring two sets of bronchial sutures, with possibly increased chances of leakage. Moreover, the longer double stump may be more difficult to cover securely with pleura during the final steps of the closure.

The excellent anatomic studies of Boyden[2] on the bronchovascular arrangements in the human lung as well as the results of certain bronchovascular injection studies carried out in this clinic with a suitable vinylite plastic medium[3] (Fig. 1) have indicated the feasibility of a simultaneous right middle and lower bilobectomy to replace individual lobectomy performed seriatim. In presenting this development, priority is not claimed since the possibility of this procedure has already occurred to other surgeons on the basis of available anatomic knowledge.[4] However, the surgical and anatomic details of such a procedure are still wanting in the literature.

SURGICAL TECHNIQUE

Under intratracheal cyclopropane, oxygen, and ether anesthesia the patient is placed in the left lateral decubitus position and the seventh right rib is resected. Adhesions are cleared from the lateral, posterior, and lateral diaphragmatic aspects of the two lobes to be removed. If the oblique fissure between the

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Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

subapical segment of the upper lobe and the dorsal (apical) segment of the lower lobe is incomplete, this is developed by sharp and blunt dissection to expose the arterial branch to the apical segment (Boyden's A 6) (Fig. 2). This vessel is doubly ligated with silk and divided. By this maneuver some mobility of the main arterial trunk is gained, and lateral access to its posterior surface

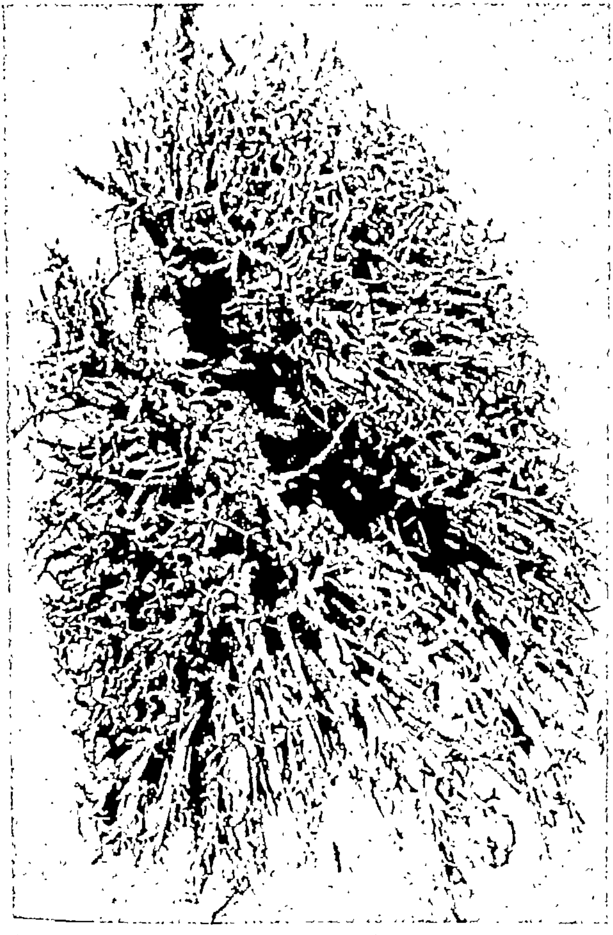

Fig. 1.—An untrimmed vinylite cast of the bronchi and pulmonary vascular tree. Right lung of a male adult, Case 7700.

on the bronchus is obtained. The arterial branch to the middle lobe lateral segment (Boyden's A 4) or the middle lobe common trunk (see below) is now sought anteriomedially, and is similarly ligated and divided. For isolation of all these vessels a blunt curved ligature carrier or a Mixter clamp is employed. It is

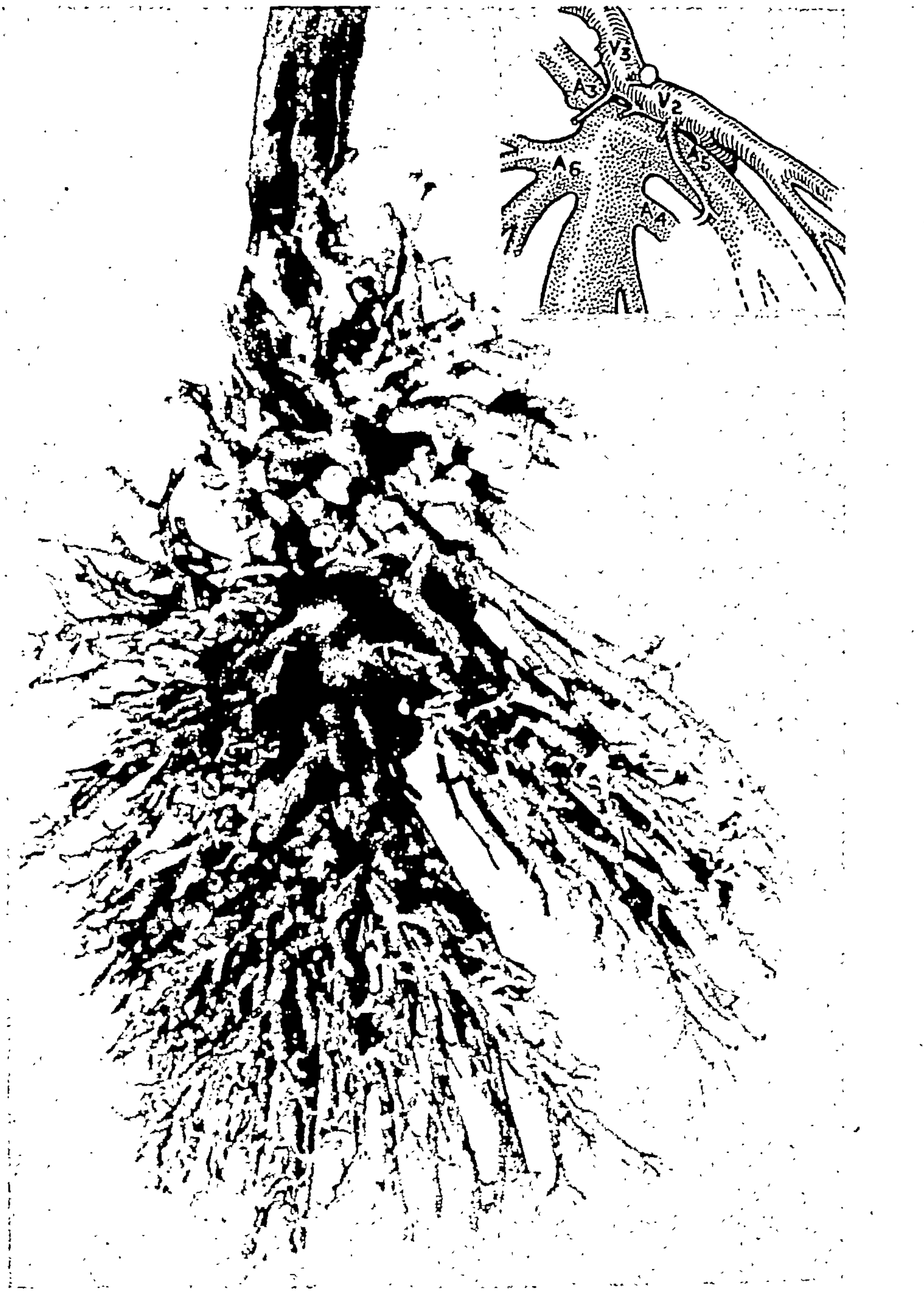

Fig. 2.—Partly trimmed cast from same specimen of Fig. 1 showing the arterial distribution, with double arteries (A4, A5) to middle lobe. Apical artery (A6) lies at an intermediate level. This branch is ligated first in the surgical approach. Note proximity of subapical artery (A3) and absence of a true intermediate artery in this case.

now possible in most cases to isolate the main arterial trunk above these two branches and below the origin of the upper lobe branches, and to divide the trunk after ligation and transfixion. (See discussion on variations.)

Next the posterior pleural reflexion from the lower lobe to the pulmonary ligament is opened. The lower pulmonary vein is isolated by dissection with a blunt clamp holding a cotton pledget moistened in 1 per cent Novocain solution. This vessel is ligated, transfixed, and divided (Figs. 3 and 4).

Attention is next directed to the fissure between pectoral segment of upper and middle lobes. Unfortunately this fissure is incomplete to some degree in over 50 per cent of individuals and must be developed. As the hilus is approached, the medial artery to the middle lobe is encountered (Boyden's A 5). The corresponding veins will be found to enter the superior (upper lobe) vein or independently into the atrium. Care should be taken in ligation and transfixion *not* to include the upper lobe venous radicles.

The intermediate bronchus is now cleared by blunt dissection, elevating the divided major arterial trunk out of the way by gentle traction forward and upward. Guide sutures are placed in the bronchial wall medially and laterally and the transection of the bronchus begun. *Without clamping proximally,* a small incision is made on the edge of the bronchus, and an interrupted silk suture, size 000, is used to approximate the cut edge. The incision is deepened and another suture or two placed. Suction is used at the stump continually with this technique to prevent aspiration of blood into the lumen. The division and suture are completed. Finally the mediastinal aspect of the middle lobe is freed from the pericardium and propericardial fat, the diaphragmatic dissection completed, and the anterior layer of the pulmonary ligament divided if this has not already been accomplished. The two lobes can now be lifted out by the common bronchial stem without any dissection in the oblique fissure between them (Fig. 11).

Repair of the mediastinal pleural defect is readily accomplished, care being taken not to interfere with the phrenic nerve in its neighboring course. Any raw surface on the pectoral division of the upper lobe is allowed to remain without infolding after detailed hemostasis.

The pleural cavity is lavaged with saline solution, all fluid aspirated, and 100,000 units of penicillin introduced. The chest wall is then closed in layers using interrupted silk technique. During the closure, the anesthetist controls reinflation of the upper lobe and this is assisted by catheter aspiration of the pleural cavity as the final layers are completed. Neither pleural cavity nor wound needs to be drained for the usual case. Postoperatively penicillin is given systemically until the temperature has been normal for forty-eight hours. Pleural aspirations are performed as indicated.

ANATOMIC VARIATIONS

The operation described here deals with the most common anatomic disposition of the vascular branches to the middle and lower lobe. Certain important variations occur with sufficient frequency to necessitate a systematic study. For this purpose twenty-five autopsy specimens of right lungs were prepared by colored vinylite plastic injections of the bronchial and vascular trees, according to a technique previously developed in this laboratory.[3] The prepared specimens were dissected sufficiently to permit study and measurement. The results are recorded in Table I, and may be summarized as shown there.

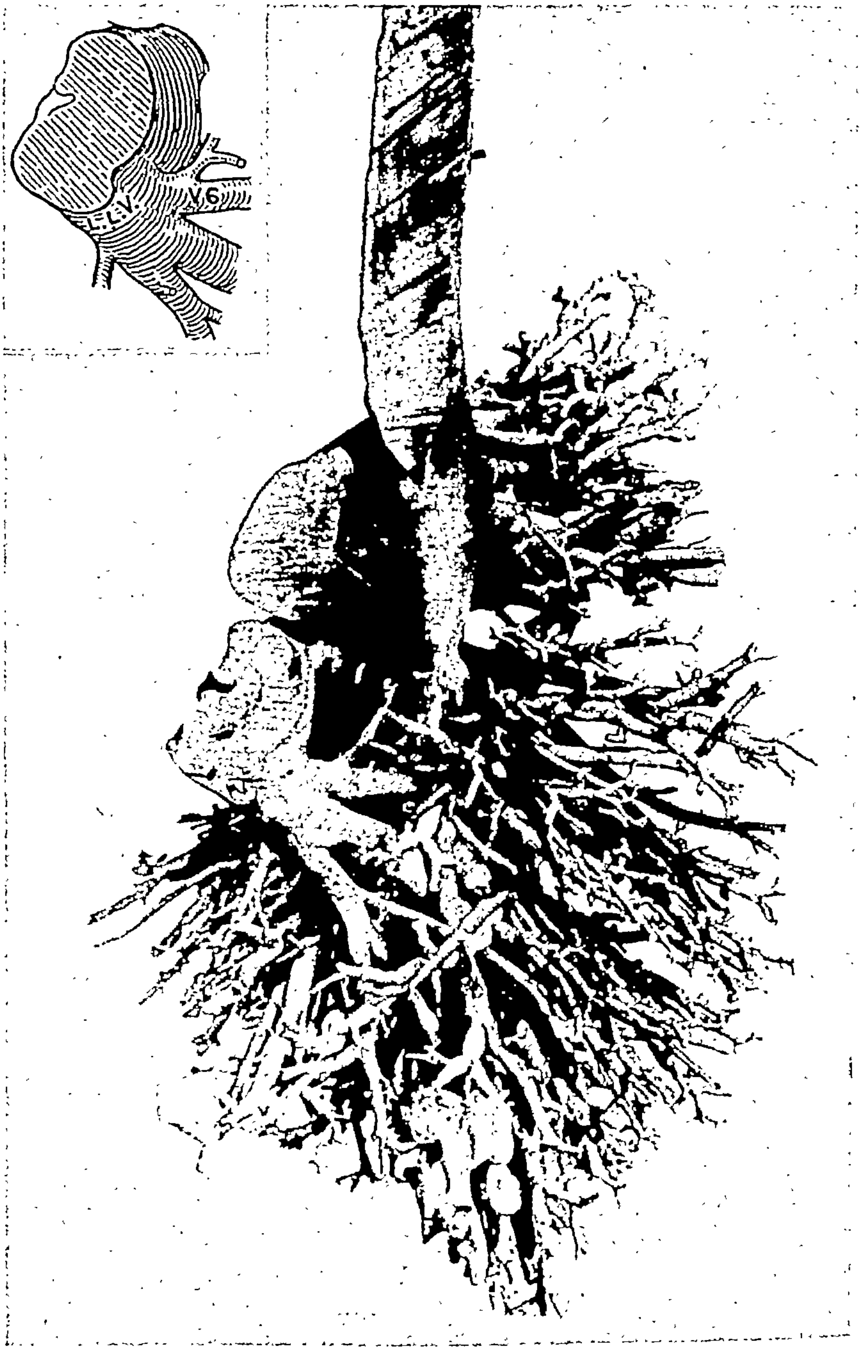

Fig. 3.—Posterior aspect of same cast, showing inferior vein and its radicles, in position for surgical ligation.

TABLE I

SPECIMEN NO.	LENGTH OF INTERM. ART. (IN MM.)	R.M.L. ARTERIES		R.M.L. VEINS		CROSSED INTERLOBAR VENOUS DRAINAGE	REMARKS
		SEPARATE OR COMMON TRUNK	DIST. SEP. OR LT. OF COM. TR. (IN MM.)	SEPARATE OR COMMON TRUNK	DRAINAGE		
7518	3	Separate	10	Common trunk	Sup. vein	No	
7541	12	Separate	5	Separate	Sup. vein	Yes*	*Small R.M.L. vein drains into pectoral vein
7545	None	Separate	10	Common trunk	Atrium	Yes*	*Apical vein of R.L.L. drains into subapical vein of R.U.L.; artery to axillary portion of subapical segment of R.U.L. arises from apical artery of R.L.L.
7563	5	Common trunk	9	Common trunk	Sup. vein	?*	*Injection too coarse
7567	None	Common trunk	5	Common trunk	Sup. vein	?	*Subapical artery of R.U.L. and apical artery of R.L.L. arise from common trunk
7602	10	Separate	5	Separate	Sup. vein	No	
7655	9	Common trunk	6	Separate	Sup. vein	?*	*Injection too coarse
7685	9	Separate	8	Separate	Sup. vein Atrium	No	
7689	11	Common trunk	12	Common trunk	Atrium	Yes*	*Vein of medial segment of R.M.L. drains into pectoral vein of R.U.L.
7693	18	Separate	6	Separate	Sup. vein	No	
7695	13	Separate	12	Common trunk	Sup. vein	No	
7700	None	Separate	10	Common trunk	Sup. vein	Yes*	*Small lateral vein of R.M.L. drains into pectoral vein of R.U.L.
7702	12	Common trunk	22	Common trunk	Atrium	Yes*	*A large vein of R.M.L. drains into pectoral vein of R.U.L.
7715	10	Common trunk	11	Common trunk	Sup. vein	No	
7726	7	Common trunk	2	Separate	Sup. vein	Yes*	*Small superficial vein of R.M.L. drains into pectoral vein of R.U.L.
7732	13	Separate	5	Separate	Sup. vein	No	
7740	7	Common trunk	14	Separate	Sup. vein	Yes*	*Vein of anterior [illegible] pectoral segment of [illegible] drains into sup[illegible] R.M.L.
7750	6	Common trunk	8	Common trunk	Atrium	Yes*	*Vein of apical [illegible] R.L.L. drains [illegible] vein of R.U.L. [illegible] drains into [illegible] R.U.L.; also a [illegible] drains into [illegible] R.U.L.
7752	None	Common trunk	16	Common trunk	Sup. vein	Yes*	*A vein of R[illegible] teriorly into [illegible] R.U.L.
7755	4	Separate	6	Common trunk	Sup. vein	No	
7758	9	Common trunk	18	Common trunk	Sup. vein	No	
7760	None	Common trunk	18	Common trunk	Sup. vein	No	*Subapical [illegible] arises [illegible] R.L.L.
7762	5	Common trunk	12	Common trunk	Sup. vein	No	
7765	None	Separate	9	Separate	Sup. vein	No	
7773	3	Common trunk	13	Common trunk	Atrium	Yes*	*One [illegible]

Variations in the Intermediate Artery.—The intermediate artery is defined as that segment of the right pulmonary arterial trunk between the lowest branch to the upper lobe (A 3) and the highest branch to the middle lobe or the common middle lobe trunk (Fig. 5). In most cases (19 of 25, or 76 per cent) a definite intermediate artery was present, with a range of 3 to 18 mm. in length, averaging 8.2 mm. In the remaining 6 specimens the artery to the subapical segment

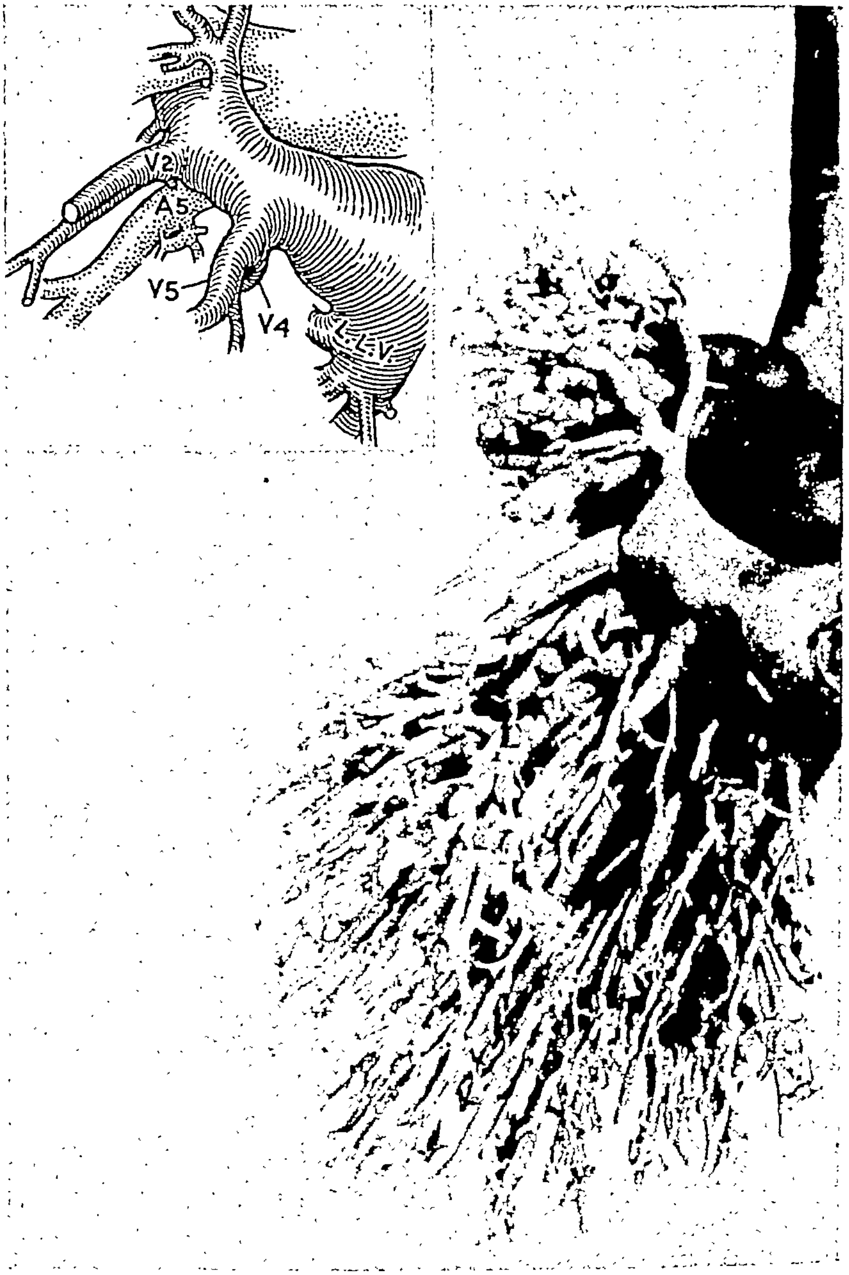

Fig. 4.—Anteromedial view of same cast, showing merging of lateral and medial segmental middle lobe veins into a common trunk which enters the extralobar portion of the superior vein. In this case the fissure between upper and middle lobe was incomplete anteriorly. A large branch of pectoral vein (V2) crosses the fissure and requires ligation.

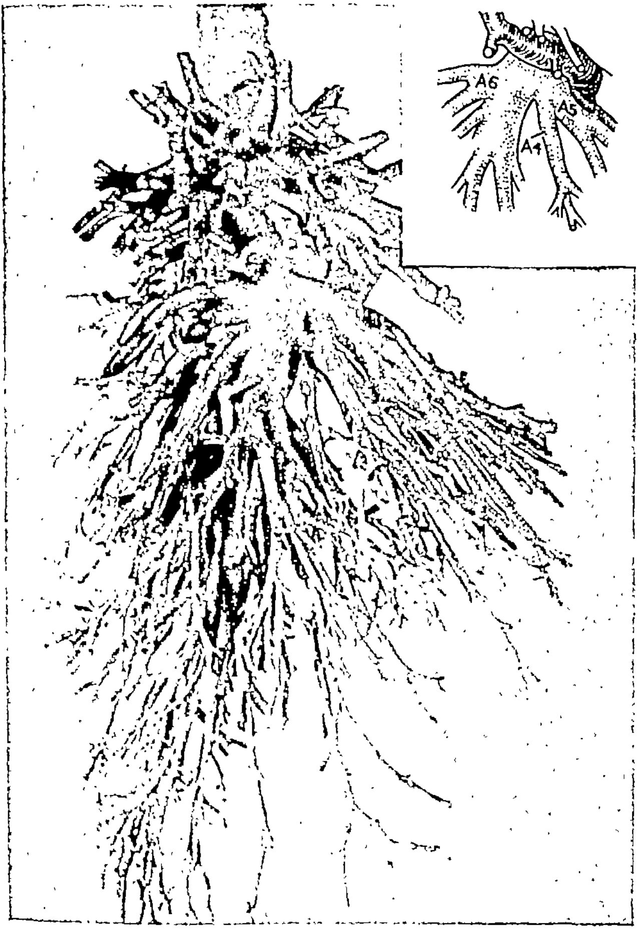

Fig. 5.—Another trimmed bronchovascular cast (7655), showing example of common middle lobe arterial trunk, and well-developed intermediate artery trunk measuring 9 mm. in length. Pulmonary artery red, vein green, bronchus white.

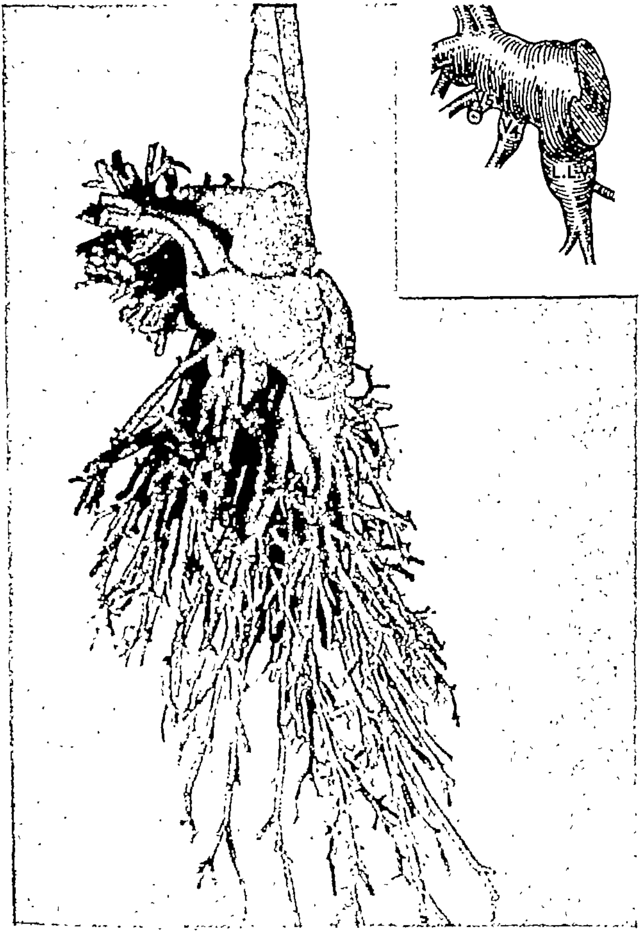

Fig. 7.—Anteromedial view of Case 7655 (same as Fig. 5) showing separate segmental vein of middle lobe (V4 and V5) entering the extralobar portion of superior vein. In this case there was a common *arterial* trunk.

of the right upper lobe (A 3) arose at the same level as the first branch to the middle lobe. Obviously, in this group of cases, surgical ligation would be accomplished through the individual lobar branches rather than the trunk.

In three instances where the intermediate arterial stem was wanting, the artery to the subapical (posterior) segment of the upper lobe or its axillary

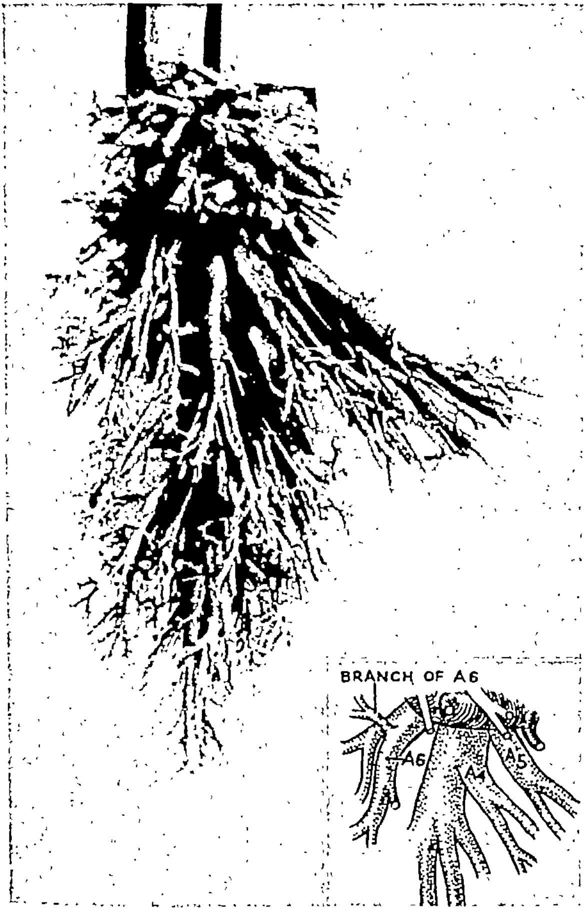

Fig. 6.—Trimmed bronchovascular cast (Case 7545) showing ascending branch from apical segment artery (A6) to subapical segment of the adjacent upper lobe. In this case the posterior portion *of the interlobar fissure was incomplete; a good example of separated middle* lobe arteries. Compare with Fig. 2.

DISCUSSION

The advantages of the bilobectomy procedure described here are several; first, a single and shorter bronchial stump deeply situated in the mediastinum; second, a single line of bronchial closure; third, an easy and adequate mediastinal pleural coverage with decreased opportunity for fistulous reopening and empyema.

The possible disadvantages are, first, the sacrifice of the lower lobe apical segment if this should prove to be uninvolved. In the absence of bilateral disease, this is not a serious objection. A second possible disadvantage is the requirement of an exact and detailed knowledge of the bronchovascular anatomy for this area, and third, the danger of compromising venous drainage from the upper lobe. In our small experience it has not been necessary to abandon this type of resection because of technical difficulties, although it is admitted that such might be the case with a very severely inflamed hilus.

SUMMARY

A technique for resection of the right middle and lower lobes as a surgical unit through the intermediate bronchus has been described.

Vascular variations based on 25 injection studies have been presented.

Results in 8 clinical trials are summarized.

The arguments for and against this procedure as compared to individual lobectomies performed seriatim are discussed.

REFERENCES

1. Lindskog, G. E.: The Lobar Distribution of Bronchiectasis in a Series of 140 Cases. (To be published.)
2. Boyden, E. A.: The Intrahilar and Related Segmental Anatomy of the Lung, Surgery 18: 706, 1945.
3. Liebow, Averill A., Hales, Milton R., Lindskog, Gustaf E., and Bloomer, William E.: Plastic Demonstrations of Pulmonary Pathology, Bull. Int. Assoc. Med. Museums, No. XXVII, pp. 116-129, 1947.
4. Kent, E. M., and Blades, Brian: The Surgical Anatomy of the Pulmonary Lobes, J. Thoracic Surg. 12: 18, 1942.

DISCUSSION

DR. WILLIAM M. TUTTLE, Detroit.—I have used this procedure in removing a lower and middle lobe in practically all such cases. A point which should be stressed is the treatment of the middle lobe vein because of the danger of injuring the vein to the upper lobe. In those patients in whom the middle lobe vein is not well demarcated I have secured all the vessels to the lower lobe as well as the middle lobe arteries and have then cut the bronchus and have left the middle lobe vein to the last. By such a method it is the only remaining structure sustaining the lobe. It is then easily and safely ligated and the lobe removed.

DR. EDWARD CHURCHILL, Boston.—Dr. Lindskog's statement that he has not been able to find this operation described in the literature means, I am certain, that he has not found as detailed a technical consideration as he has given us today. To keep the record straight regarding developmental steps, however, leads me to refer to the right lower and middle lobe lobectomy, with section through the intermediate bronchus "after isolation and separate ligation of the branches of the pulmonary vessels" reported in the JOURNAL in February, 1933 (page 257). This operation was performed on Aug. 10, 1931, for a tumor classified first as adenocarcinoma and later recognized as bronchial adenoma. It was precisely the operation described by Dr. Lindskog today, with interlobar hilar dissection, primary closure of the intermediate bronchus, coverage of the stump with adjacent lung tissue, and temporary catheter drainage with suction to expand the remaining lobe. The patient is still living and well.

The most important landmark in this operation is encountered as the dissection is carried up the bronchus. This is the large tributary of the superior pulmonary vein called the "great upper lobe vein" by Appleton and "the posterior vein (V^3)" by Boyden and Scannell. It passes beneath the upper lobe bronchus and above the intermediate bronchus, to enter the superior pulmonary vein, and anomalies are rare except in its more peripheral tributaries. The bronchus may be divided at the inferior border of this vein or after carrying the dissection upward beneath it. The vein itself must be protected from injury.

DR. LINDSKOG.—I want to thank Dr. Tuttle for his discussion of the use of the posterior approach. We also have varied the approach a bit, and I think the posterior is useful in an occasional instance. I apologize to Dr. Churchill for not having seen his case report—it probably did not appear with a title we would recognize.*

I would like to conclude the discussion with a slide or two to further clarify the anatomy involved.

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*Churchill, Edward D.: The Surgical Treatment of Carcinoma of the Lung, J. THORACIC SURG. 2: 254, 1932. Case 4 (page 257) reads as follows:

"On August 10, 1931, the lower and middle lobes of the right lung were removed after isolation and separate ligation of the branches of the pulmonary vessels supplying them. . . . The stump of the bronchus was fixed by two sharp hooks and a continuous suture of chromicized catgut used to close the aperture. The peribronchial and mediastinal tissue was drawn over the line of suture by interrupted mattress sutures. In separating the middle lobe from the upper lobe in the area of anatomic fusion, the electrocautery was employed. The denuded surface of the upper lobe thus produced was drawn over the bronchial stump and sutured to the mediastinum. A catheter was inserted between the ribs just above the diaphragm."

AN EXPERIMENTAL STUDY IN BRONCHIAL ANASTOMOSIS

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DURING the last decade increasing attention has been directed to healing and regeneration within the tracheobronchial tree. The advent of pulmonary resection with the necessary importance of a secure bronchial closure probably has furnished the greatest stimulus to study in this direction. Rienhoff, Gannon, and Sherman, in 1942, showed that the bronchus following pneumonectomy will heal securely with airtight closure of the pleura over the bronchial stump. Taffel, in 1940, published experimental work on the repair of tracheal and bronchial defects in dogs. Full-thickness windows were cut from the trachea and covered with mucosa. Within three weeks mucous glands were observed to appear in the submucosa. Daniel published experiments in 1948 concerning the use of rigid tubes to bridge defects of the trachea and primary bronchi. The regeneration of the tracheobronchial wall over the tube was closely observed and discussed. His experience indicated that fibroblasts in the early scar were the analage of cartilage cells. He believed that cartilaginous rings were formed from such anlage. Hanlon reported the use of gelatin sponge in the closure of defects of the bronchus and the closure of the bronchial stump following lobectomy. The sponge formed an adequate scaffold for the ingrowth of fibrous tissue and a wall for the ingrowth of mucosa.

The significant observation one may derive from the work of these authors is the remarkable powers of regeneration and healing within the tracheal and bronchial walls. It would seem to follow that the important factor in covering and healing of bronchial defects is an airtight closure that will allow ingrowth of connective tissue and epithelization. No matter whether the bronchus is being closed, defects in the wall are being covered, or a bronchial anastomosis is being effected, the process of healing is similar.

It was desired by the authors of these experiments to study end-to-end anastomosis of the bronchus, using dogs as the experimental animal. The problems undertaken were two and the experiment divides itself into two groups:

Group 1. Resection of segments of major bronchi and anastomosis.
Group 2. Creation of strictures within the major bronchi, their resection and re-establishment of bronchial continuity by anastomosis.

METHODS

Thirty-three dogs of nonspecific pedigree were used. The surgery was performed under endotracheal ether anesthesia, the lungs being inflated rhythmically by intermittent insufflation of the anesthetic. A small motor furnished the force for delivery of the air and ether to the lungs.

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Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

Group I.—Twenty dogs were used. The animals were divided into two groups depending on the method of suturing the bronchus.

(a) In ten dogs a cylinder of one of the main bronchi was removed and an anastomosis was performed by simple through-and-through interrupted 00000 silk sutures. All knots were placed on the outer surface of the bronchial wall. The pulmonary hilus was exposed, and the pleura over the bronchus was incised. Care was taken to open the pleura overlying the bronchus in a longitudinal manner. It was felt from previous experience that opening the pleura transversely could result in a significant interruption of the pulmonary plexus and the lymphatic drainage of the lung.

In the first five dogs a rubber shod clamp was placed on the proximal portion of the main bronchus, a one-fourth inch cylinder was removed, and the walls were approximated as just described. Penicillin, 50,000 units, was poured over the suture line and the pleura was closed over the bronchus. The lung was completely inflated before the chest wall was closed. The animals were bronchoscoped weekly and the suture line observed.

All animals developed a varying degree of stenosis and four had a stormy postoperative course. Penicillin, 50,000 units, was given intramuscularly twice daily and the bronchus was aspirated periodically. One animal developed an early progressive stenosis, lost weight, and was sacrificed within one month. An almost complete stricture was found at the suture line with a consolidated, suppurating lung distally. The bronchial wall was densely infiltrated with leucocytes, but there was complete epithelization. The suture line was red and edematous and sutures were lying free in the bronchial lumen. Two other animals developed a more slowly progressive stenosis, were chronically ill, and lost weight. Bronchoscopy showed complete epithelization of the wall but a gradual loss of lumen with accumulation of pus distally. These dogs were sacrificed in three and four months. Almost complete strictures were found. Both had local empyemas around the suture line. These were walled off pockets and a general empyema was not present. Both presented chronic suppuration of the lung with diffuse severe bronchiectasis.

This series of events was attributed very early to the use of a clamp on the bronchus. The two surviving animals were followed with bronchoscopy and were sacrificed at six and eight months. One developed a slowly progressive stenosis of the bronchus and repeated aspiration was done. The stricture became almost complete in six months and the dog was sacrificed. The lung presented a dense atelectasis and fibrosis with bronchiectasis but there was no frank suppuration. The bronchial wall at the suture line was markedly thickened and somewhat wrinkled. There was a fairly dense infiltration of lymphocytes in the wall and a heavy growth of scar tissue. The fifth animal was sacrificed in eight months. During the first two months there was very little evidence of any loss of lumen at the suture line and the area was completely epithelized. However, there was a gradual contracture at the suture line which in six months resulted in about 20 per cent stenosis of the bronchial lumen. In another two months there was no significant increase in this stricture. The animal was sacrificed at the end of eight months. His general condition was excellent. A 20 to 25 per cent loss of lumen was found due to a stricture at the suture line. The lung distally was entirely normal in appearance. It inflated well and on cut section was grossly normal.

It was felt that the use of a clamp of any type on the bronchus resulted in a high-grade stenosis at the suture line, with subsequent suppuration and bronchiectasis. At surgery, after the clamp had been removed, the bronchus resumed its normal shape, the lung expanded, and postoperative bronchoscopy revealed no immediate narrowing. However, the stenosis was rapidly progressive in one animal, less rapid in three, and insidious in the last. It was thought that the two instances of local empyema in this group represented a late breakdown of the suture line. The clamping and crushing of the bronchial wall produced injury to the area which led to the formation of scar tissue and to high-grade stenosis. When trauma from the clamp was excessive, a marked amount of granulation tissue formed and early stenosis resulted.

In order to effect *temporary bronchial occlusion during surgery, a rubber balloon* was thereafter used. This was placed in the proximal end of the bronchus, in place of the clamp. An inflatable cuff on a small catheter was used at first, but this was occasionally unsatisfactory. The amount of air necessary to inflate it sufficiently varied and if too much air was used the cuff slipped into the trachea. To avoid this difficulty several sizes of balloons were made from old rubber gloves and the balloon tied shut with a piece of silk. The pressure in this type of balloon is low and it could easily be forced into the bronchus. It adapted itself readily to the conformation of the wall and by gentle traction on the silk, it was prevented from slipping into the trachea. Before the last two sutures were tied the balloon was punctured with a needle and withdrawn through the suture line. The distal end of the bronchus was isolated with sponges to keep aspiration of blood at a minimum.

Bronchoscopy was done on the five dogs in which a balloon was used immediately postoperatively and weekly thereafter. Following surgery there was a reddened edematous area at the suture line. Within five days there was a thin ridge of granulation tissue. Within two to three weeks most of the granulation tissue was no longer visible and the suture line had attained a smooth appearance. The area was slightly raised, injected, and edematous. With the passage of time this area flattened out and became white and glistening. However, at every point through which a suture pierced the mucosa there was some redness and edema. Even though the knots had been tied on the external surface, some had rotated and now lay in the lumen of the bronchus. Some of the sutures were completely covered with mucosa. The presence of the sutures in the mucosa presented for six to eight weeks a definite source of irritation and in most of the specimens a few could be seen four to five months later, though they were completely covered with epithelium.

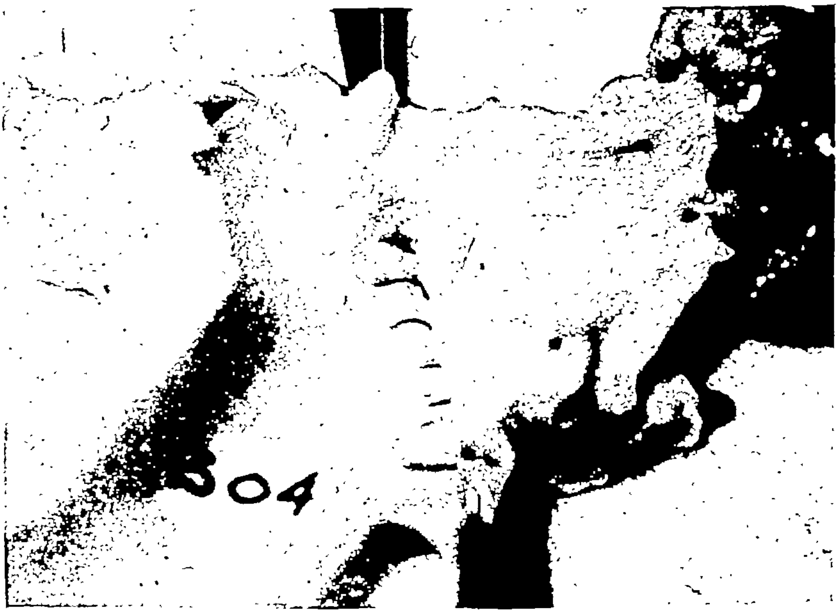


Fig. 1.—Showing specimen three months after simple through-and-through anastomosis. Line of union is just proximal to the upper lobe orifice. Some of the knots have rotated into the lumen.

Fig. 1 is a photograph of a specimen at three months after anastomosis. The sutures are seen as described previously. There is a very slight ridge where the mucosal edges meet. The line of union is just proximal to the upper lobe orifice which was uneffected by the surgery.

These dogs were sacrificed at periods from one month to eight months, microscopic sections were taken through the suture line, and the specimens were preserved. It was found that at one month there was complete epithelization at the suture line and union of the bronchial wall by fairly dense connective tissue. Most of the leucocytic infiltration had disappeared and mature scar tissue was present. The epithelium was low cuboidal in type. Fig. 2 is a photomicrograph of such a specimen. In the middle of the field just beneath the mucosa can be seen two pieces of silk which have been completely covered with epithelium. The wall is made up of dense connective tissue. In several areas cartilage can be seen undergoing degeneration. In some specimens within four to six weeks the low cuboidal epithelium has been converted into a fairly normal-appearing bronchial epithelium. Fig. 3 is a section of a specimen at one month. In this section the epithelium is early columnar in type. This is seen in the left portion of the field.

The only pertinent changes following this, in the animals sacrificed at longer intervals, lay in the fate of the sutures and the tendency to form a slight ridge at the suture line following contraction of the scar tissue. Around all of the sutures there was, in microscopic section, a significant foreign body reaction. Some of the sutures slowly worked into the lumen of the bronchus, were cast out, and the area was epithelized. Other sutures, especially those around a cartilage, remained in the wall and the endobronchial portion became completely epithelized. This epithelization of the sutures is demonstrated well in Fig. 2.

The early ring of granulation tissue in the lumen of the bronchus was constant in all of the dogs anastomosed in this manner. The presence of this tissue in the lumen was not desirable. It was necessary for the epithelium to grow over this ridge of tissue and this caused some loss of functional lumen, however, in several weeks this area flattened out. The presence of the sutures through the mucosa and lying in the lumen of the bronchus was a source of constant irritation within the bronchus. This seemed especially important when the suture line involved the wall of the upper lobe orifice or one of the lobar bronchi as it did in several of the animals. Here a moderate amount of granulation tissue, together with edema, was in one instance enough to prevent proper aeration and drainage of the lobe. To improve the suture line a very accurate approximation of the mucosa seemed important, to avoid the granulation tissue ridge. It was desirable to place the sutures so that as little as possible of the suture material would lie within the lumen of the bronchus. The use of an averting mattress suture seemed likely to satisfy in part these requirements.

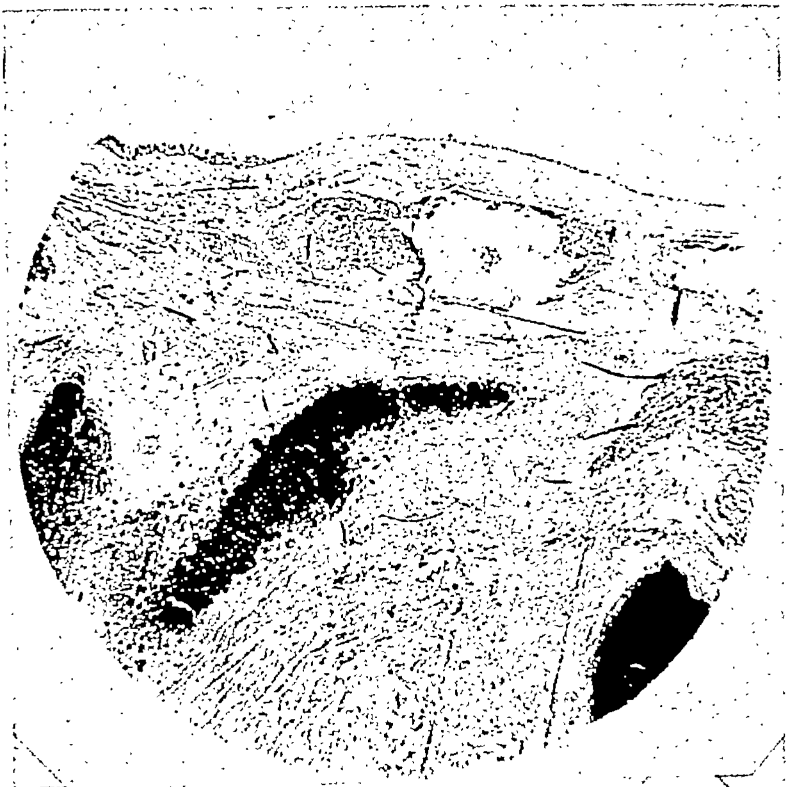
(b) To test this hypothesis ten dogs were used. Thoracotomy was performed in the same manner as before. A balloon was used to plug the proximal bronchial segment. A single row of horizontal everting mattress sutures was used, thus turning up a very small cuff.

The actual technique varied somewhat with the size of the bronchus. In the larger animals, while removing a section of the bronchus, it was possible to cut close enough to the cartilage on either end of the removed cylinder to leave enough bronchial wall soft tissue to allow for closure without disturbing the cartilages. In others attempts were made to remove a cartilage without tearing its bed, and to use this tissue for the anastomosis. This proved tedious and usually resulted in tears through the bed. Therefore, in the smaller animals, the cartilaginous ring was cut across transversely, without cutting the mucosa, in three places to allow a cuff to be turned up without undue distortion. The sutures were placed close to the cartilage. When sufficient tissue was not present between the rings for anastomosis, the sutures were placed behind the cartilage ring, thus turning up a larger cuff. Immediately postoperatively, there was no raw surface at the suture line and a cleft was seen where the cuff was turned outward. Bronchoscopy was done on the dogs weekly. In most animals there was never a ring of granulation tissue in the lumen at the suture line. From the day of surgery the bronchial wall appeared smooth. During the first week there were no sutures visible through the bronchoscope. There was absence of the prominent redness and edema seen in the animals of group a. The dogs did less coughing and seemed to have a smoother postoperative course.

If a large cuff had been turned up the bronchus stretched out and in several weeks some of the sutures could be seen; however, even then, there was no granulation tissue present in the lumen.

Some of the sutures cut through the wall and were cast off into the lumen but this was not as constant as with the group a animals. The rest of the sutures were soon covered over with epithelium. At first one could see a groove where the cuff had been turned but

Fig. 2.



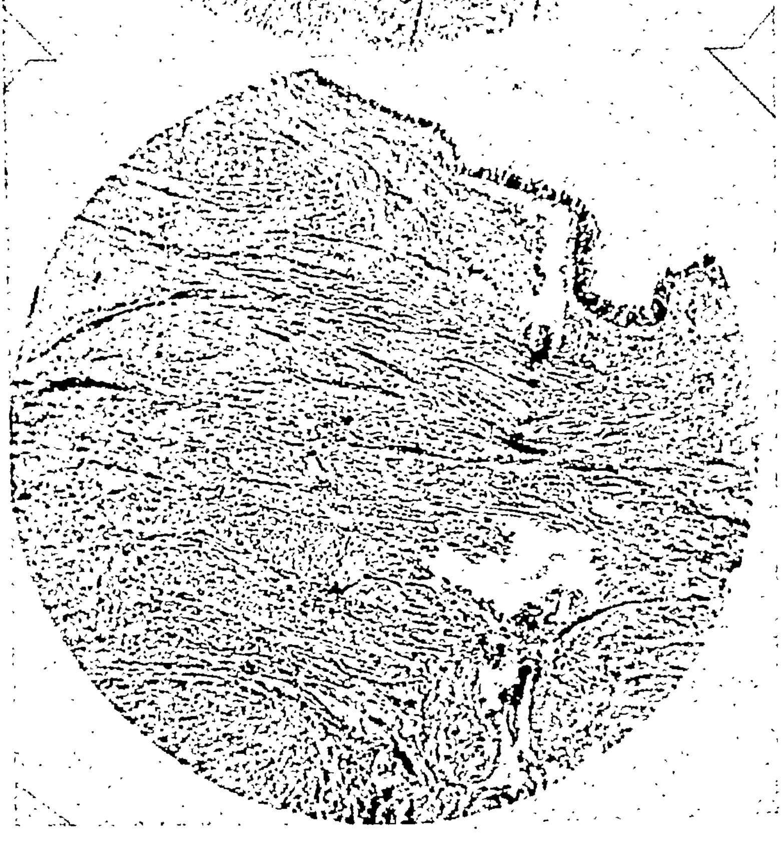


Fig. 3.

Fig. 2.—Photomicrograph of specimen six weeks after anastomosis. Just beneath the mucosa two silk sutures have been completely covered with epithelium. Low cuboidal epithelium is present. Degeneration of cartilage can be seen. (×75.)

Fig. 3.—Photomicrograph of specimen one month after anastomosis. One can see where the suture has traversed the wall. Early columnar type of epithelium can be seen in the left corner. Dense connective tissue is present in the wall. (×125.)

this soon flattened out and the wall became very smooth with a few sutures visible completely covered with mucosa (bronchoscopic observations). Fig. 4 shows a specimen at three and one-half weeks, Fig. 5 one at eight weeks, and Fig. 6 one at ten weeks. In Fig. 4 the suture line has gone across the floor of the upper lobe orifice and there is a probe in the orifice of the upper lobe. Several of the sutures have cut through the mucosa, but no sutures are visible and there is very little reaction at the suture line. Fig. 5, presenting a specimen at eight weeks, shows several sutures to be barely visible but these are completely covered with epithelium. There is no longer the groove present seen in Fig. 4, there is no inflammation at the suture line, *and no loss of lumen from scar.* In Fig. 6, at ten weeks, one suture is visible, the bronchial wall is entirely smooth, and there is no evidence of stenosis. It is difficult to identify the suture line from the mucosal surface but at the cut edge one can see the turned up wall. Fig. 7 is a photomicrograph of a specimen at two months. There is a slight groove in the mucosa where the cuff has been turned and it demonstrates how the entire wall has flattened out. There is a moderate infiltration with leucocytes, and fibroblasts are present.

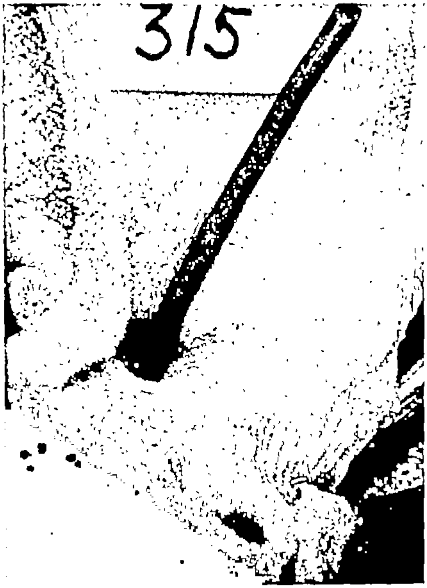


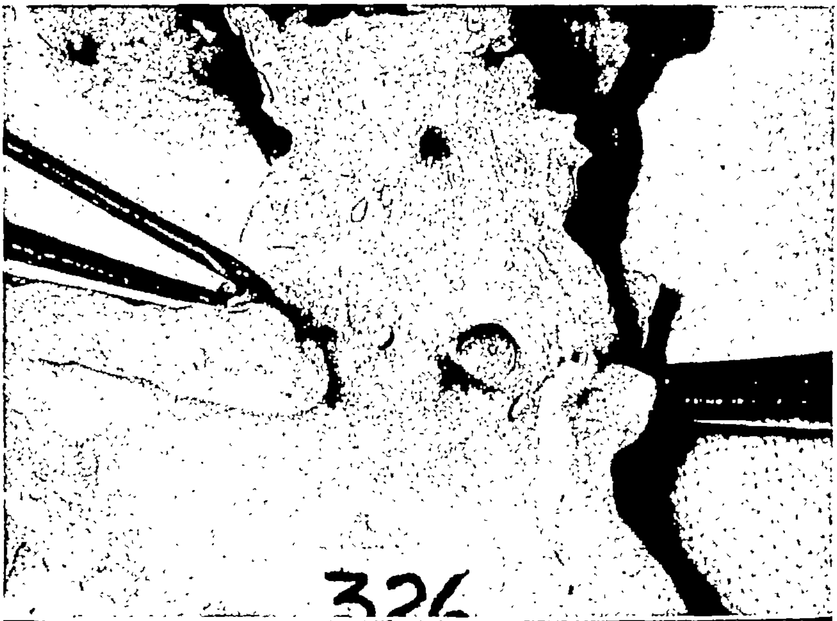
Fig. 4.—Photograph of specimen three and one-half weeks after anastomosis by cuff technique. Stricture of right main bronchus was resected. Suture line goes across floor of upper lobe orifice and a probe is in the orifice. Several sutures have cut through the mucosa but none are visible. Slight groove can be seen at the mucosal junction where the cuff has been turned.

It was felt that this method of suturing represented a definite improvement upon those in group a. In none of these ten dogs was there an appreciable loss of lumen at the suture line even at eight months. The lungs were grossly normal. Most of the improvement with this type of suturing lies within the first two to three months. In dogs sacrificed at six and eight months there was no great difference between the last dogs of group a and those of group b.

Group II. Creation of Strictures Within the Major Bronchi, Their Resection, and Reestablishment of Bronchial Continuity by Anastomosis.—Thirteen dogs were used. Stenoses were created in either main bronchus by the following methods:

(1) Injection of 30 per cent silver nitrate into the bronchial mucosa, 3 animals.

Fig. 5.



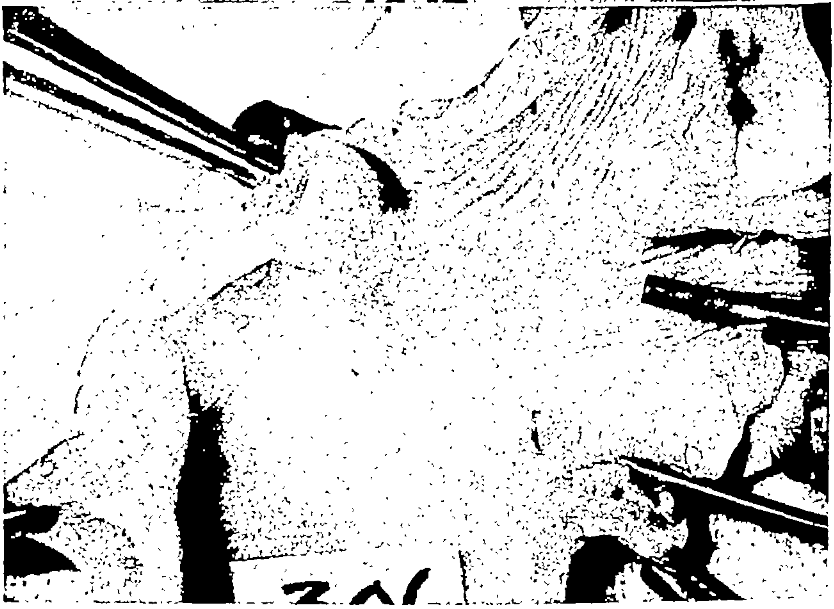


Fig. 6.

Fig. 5.—Photograph of a specimen eight weeks after anastomosis by cuff technique. A stricture of the right main bronchus had been resected. Two sutures are barely visible and completely epithelized. The groove seen in Fig. 4 cannot be seen here. The wall has flattened out. Line of anastomosis lies immediately in front of upper lobe orifice.

Fig. 6.—Photograph of a specimen ten weeks after anastomosis by cuff technique. A stricture of the main bronchus had been resected. Wall is smooth with no evidence of stenosis. One suture barely is visible. Suture line is difficult to identify but at the edge the turned up wall can be seen. A probe lies in the upper lobe orifice.

(2) Cellophane wrapper around the bronchus, 4 animals.
(3) Umbilical tape wrapper around the bronchus, 6 animals.

The use of silver nitrate proved difficult. It was necessary to inject the solution through the bronchoscope, making use of a long needle carrier, hypodermic needle, and syringe. The main bronchus is extremely short. Usually some of the caustic material escaped from the wheal or needle and ran down into the lobes. Painting with sponges involved the same difficulty. These procedures resulted in a severe bronchopneumonia and the ulceration and stenosis of the bronchus was not localized. The formation of the stenoses required numerous treatments with the silver nitrate. Three animals were treated in this manner. The time between the use of the silver nitrate and resection of the stenotic area varied between two and ten weeks.

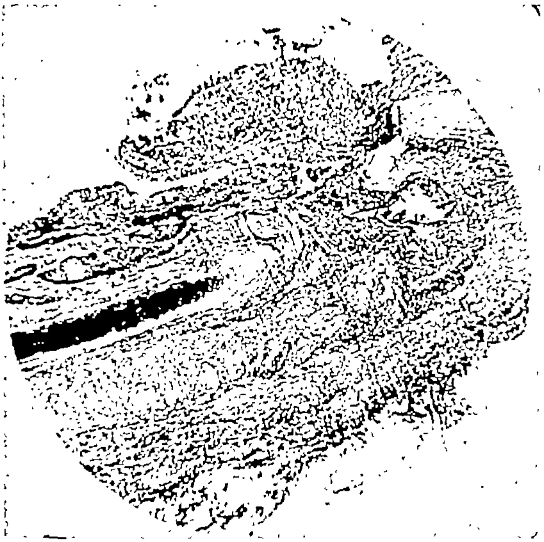


Fig. 7.—Photomicrograph of a specimen two months after anastomosis. The groove where the mucosa has been turned inward, can be identified. The wall has flattened out considerably. (×75.)

In the remaining ten dogs the chest wall was opened through the fifth rib bed, and the pleura opened and reflected off the bronchus. A mechanical stricture of about 60 per cent of the bronchial diameter was created by placing a cellophane wrapper (four dogs) or umbilical tape (six dogs) around the bronchus. The cellophane was tightened to give the desired stenosis and sutured together with 00000 silk. The umbilical tape was tied at the desired tension. The dogs were bronchoscoped and the stenoses visualized to see if the desired result had been accomplished. The cellophane had not been treated with polythene.

The use of cellophane was discontinued because it occasionally slipped, requiring another operation to reproduce the desired stricture. Bronchoscopy was done on the dogs weekly. If the animals developed obstructive symptoms, they were aspirated, given penicillin, and operated upon early. The time period between creation of the stenoses and the resection varied between thirteen days to two and one-half months. One dog developed a severe stenosis following silver nitrate treatments due to edema and ulceration. He was

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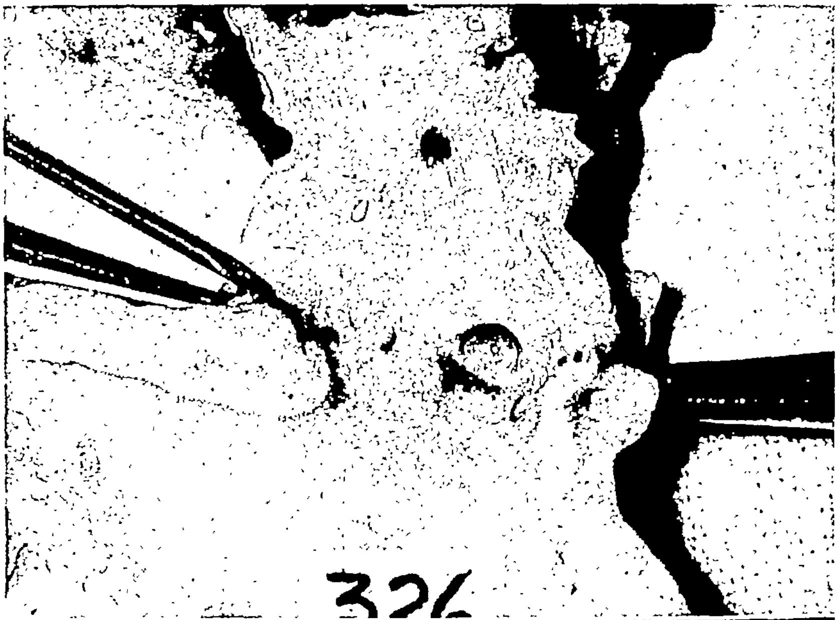

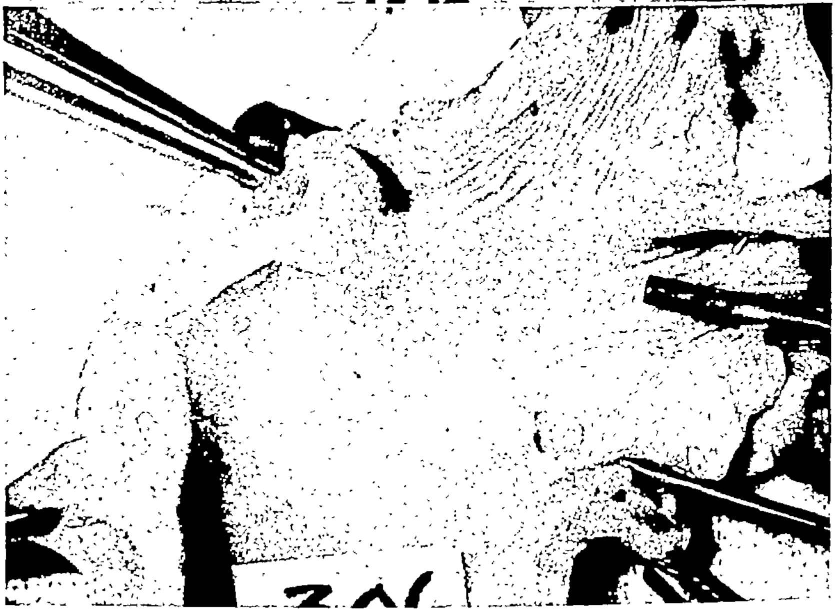

Fig. 6.

Fig. 5.—Photograph of a specimen eight weeks after anastomosis by cuff technique. A stricture of the right main bronchus had been resected. Two sutures are barely visible and completely epithelized. The groove seen in Fig. 4 cannot be seen here. The wall has flattened out. Line of anastomosis lies immediately in front of upper lobe orifice.

Fig. 6.—Photograph of a specimen ten weeks after anastomosis by cuff technique. A stricture of the main bronchus had been resected. Wall is smooth with no evidence of stenosis. One suture barely is visible. Suture line is difficult to identify but at the edge the turned up wall can be seen. A probe lies in the upper lobe orifice.

presented a 20 per cent stenosis. This was not due to scar tissue in the wall of the bronchus but to faulty placing of the sutures. Large bites were taken and the membranous portion of the bronchus was not accurately apposed. When the anastomosis was completed there was a partial stricture from the actual anastomosis.

Within six weeks numerous sutures were seen in the lumen with varying degrees of reaction around them. Fig. 1 shows a specimen at three months. Six sutures are visible. The wall otherwise is completely epithelized and there is no loss of lumen from the suture line.

Fig. 8 represents a specimen at five months. Several sutures were visible but completely epithelized. The mucosa was columnar in type and ciliated as seen in Fig. 9, which is a section through the bronchial wall at the suture line. The round-cell infiltration in the right portion of the field, beneath the mucosa, is due in part to the presence of a suture. The mucosal surface of the suture line was slightly raised. At seven months no sutures were visible on the mucosal surface. There was a slight ridge on the mucosal surface of the suture line, representing a slight loss of lumen from the anastomosis.

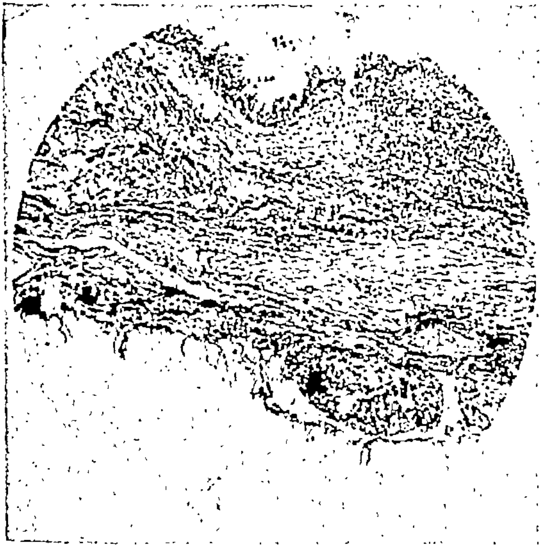

Fig. 9.—Photomicrograph of a section through the suture line five months after anastomosis. Fibers of a suture can be seen on the edge of the outer wall and there is considerable round-cell infiltration beneath the mucosa on the right, where a suture has cut through. The epithelium is ciliated columnar. (×125.)

In one animal a stricture of the left lower lobe was resected. The animal was sacrificed in two months. The lower lobe was grossly normal in appearance. There were two small ulcerations in the mucosa where sutures had sloughed out. There was approximately a 15 per cent loss of lumen from stricture formation but all of the lobular orifices were patent and the lobe well expanded.

In one of the dogs, it was found at operation that the tape used to create the stricture had cut through the outer surface of the bronchus and was completely covered. The stricture was difficult to identify, and it was necessary to open the bronchus to find the tape. It was completely covered by epithelium and lying within the bronchial wall. It was believed that it would have been cast off into the bronchus in time.

DISCUSSION

It is appreciated that the physical arrangement of the pulmonary hilus of a dog is more conducive to surgery than the bronchus in man. In the dog, the fissures are complete and the main bronchus is readily and easily exposed. The possible clinical applications of these experiments are therefore not clear. However, one can postulate several situations in which the procedure could be used should the bronchus prove accessible:

(1) Traumatic rupture of the bronchus
(2) Adenoma of the bronchus
(3) Benign tumor of the bronchus requiring resection
(4) Local stricture associated with trauma, foreign body, chemical burn, etc., with evidence of normal pulmonary parenchyma distally.
(5) Accidental severing of the bronchus during surgery.

In two of the dogs a Gelfoam sponge was placed over the outer surface of the suture line and the pleura closed in the usual manner. When these animals were sacrificed several months later a much denser area of scar tissue was encountered than was expected or found in the other animals. The papers of Hanlon and Daniel have demonstrated the manner in which Gelfoam acts as a lattice for the ingrowth of fibrous tissue. Because of the tendency to increase the amount of scar tissue at the anastomosis, its use was discontinued in the experiments on bronchial anastomosis. Ideally one wished to have only enough scar tissue at the anastomosis to secure union.

It would follow from these experiments, if one can achieve an accurate approximation of mucosa to mucosa, that the epithelium acts as a bridge for the ingrowth of granulation tissue in the outer wall and there is a minimum of scar at the union of the mucosa. In these experiments the use of horizontal mattress sutures, turning up a small cuff, offered a result superior to that when simple through-and-through sutures were used.

The use of silk carries some objections. It is not absorbable and the majority of the sutures are cast off into the lumen of the bronchus. If cast off they leave a path of granulation tissue through the wall to the lumen. If incased within the wall they cause a significant amount of scar tissue. In these experiments the silk was waxed in all but the first few to prevent dragging submucosal tissue through the needle holes. In one animal 00000 Nylon was used. This suture presented a smooth surface and was very easy to work with. Some animals are under observation now in which 00000 medium chromic catgut was used for the anastomosis.

In some of the specimens the suture line went across the upper lobe orifice. Healing occurred readily without atelectasis of the lobe or stenosis of the orifice. In these cases the use of the cuff technique is especially valuable. It prevents the ingrowth of granulation tissue between the mucosal edges, and there is less likelihood of stricture formation at the orifice.

From the results of the use of rigid clamps on the bronchus in the first five dogs of Group I (a) it would seem hazardous to use such a clamp on the proximal end of the bronchus in pulmonary resection. We feel this true not because of the dense scar tissue that was formed, but because in two dogs bronchopleural fistulas with local empyemas occurred.

The specimens were preserved and mounted in gelatin after the technique described by Howard.*

CONCLUSIONS

1. The bronchus has been divided and anastomosed in thirty-three dogs.
2. Two methods of anastomosis were used, namely, a simple end-to-end closure and an everting cuff closure.
3. The occurrence of unsatisfactory incidents was much less in the everting cuff method.
4. Bronchial stenoses were produced and treated by resection and anastomosis with satisfactory results.
5. The problem and its clinical application has been discussed.

REFERENCES

1. Rienhoff, W. F., Jr., Gannon, J., Jr., and Sherman, I.: Closure of Bronchus Following Total Pneumonectomy, Ann. Surg. 116: 481, 1942.
2. Taffel, M.: The Repair of Tracheal and Bronchial Defects With Free Fascia Grafts, Surgery 8: 56, 1940.
3. Daniel, Rollin A., Jr.: The Regeneration of Defects of the Trachea and Bronchi, J. THORACIC SURG. 17: 335, 1948.
4. Hanlon, C. R.: Observations on the Use of Gelatin Sponge in Closure of Experimentally Produced Defects of the Bronchus, Surg., Gynec. & Obst. 86: 551, 1948.
5. Howard, W. L.: Method for Preservation of Anatomical Specimens, Pathology Department of Maybury Sanatorium, Northville, Mich. Personal communication.

DISCUSSION

DR. TUTTLE.—We have used this method in the human being. The patient was a man who had had a snare type of lobectomy done some ten years previously. He recently returned to us bleeding from the lung and a bronchogram revealed that he had a bronchiectasis of the lingula, which had not been removed at the time of the previous operation. Re-exploration and a lingulectomy were done. It was then realized that the dorsal division of the lower lobe had been left at the time of the snare lobectomy. In the process of cutting across the main bronchus above the dorsal division bronchus it was suddenly realized that because of the shortening which had occurred from the previous lobectomy, the division would have to come above the upper lobe bronchial orifice. When this situation was evident it was decided to sever the bronchus and anastomose the upper lobe bronchial orifice to the main left bronchial stem bronchus. This was done with interrupted sutures of fine silk. The postoperative course was uneventful with the exception of one incident of atelectasis on the fourth postoperative day. Bronchoscopy was done at this time and the suture line was well visualized and seemed to be well healed. He has made an uneventful recovery and the left upper lobe is completely aerated.

DR. ROLLINS HANLON, Baltimore.—I have enjoyed this presentation by Dr. Jackson and his associates. We all realize that results in experimental studies on animals cannot be applied without reservation to human beings. However, I am sure that the principles he has enunciated are valid.

Dr. Jackson tested the use of gelatin sponge as a supplement to conventional bronchial suture and discontinued its use because of the fibrous tissue reaction which was noted in the vicinity of the sponge. As we have pointed out elsewhere, this fibrous tissue reaction is beneficial in the early stages of bronchial repair, since it is capable of providing, without the use of sutures, the airtight closure that is essential in all types of surgery of the bronchus. Unless it be demonstrated that this fibrous tissue will subsequently constrict the bronchus, we should not reject the possibility of its use as an additional safeguard in bronchial suture.

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*Dr. Eugene Woodruff was consultant pathologist in the evaluation of the specimens.

I should like to refer to the use of gelatin sponge in another type of experiment, where it was used to repair window-like defects in the bronchial wall of dogs. In a high percentage of instances there was satisfactory healing, although in no case were sutures used to hold the material in place against the defect. On bronchoscopic examination several months later there was smooth healing without evidence of constriction. Similarly, in excision of the left upper lobe in the dog, with the bronchial stump covered merely by gelatin sponge without suture, bronchoscopy at intervals for several months showed smooth healing without granulations in the stump. This technique is suggested as an ancillary measure in the repair of bronchial defects occurring during excisional surgery of the lung or bronchus.

DR. OSLER ABBOTT, Atlanta.—I wonder whether or not a vertical figure-of-eight suture might not be more beneficial than interrupted mattress sutures, with less occluded blood supply. We have utilized this in recent work in resection on the lateral tracheal wall in carcinoma of the upper lobe. These sutures are not grossly visible on bronchoscopy, and I believe they are quite satisfactory as a method of anastomosis.

THE RECOGNITION AND CORRECTION OF CONSTRICTIVE PERICARDITIS

EMILE HOLMAN, M.D.
SAN FRANCISCO, CALIF.

THE successful correction of constrictive pericarditis is dependent upon two factors: (1) the clinical recognition and treatment of the disease at a time when the condition of the myocardium and circulatory apparatus will permit recovery once the heart has been released from bondage, and (2) upon an adequate pericardiectomy by the operating surgeon.

The recognition of the disease falls obviously and inevitably upon the internist, who must at all times be aware of its imminent possibility in any case of obscure ascites. It is said that a number of cases of constrictive pericarditis amenable to correction by operation are now improperly labeled tuberculous peritonitis, cirrhosis of the liver, valvular heart disease, or ascites of unknown origin.

The characteristic features common to most cases of constrictive pericarditis are: (1) increased venous pressure, (2) some form of peripheral edema associated usually with ascites or pleural effusion or both, (3) a quiet heart with normal blood pressure, and normal heart sounds, (4) an electrocardiogram exhibiting a low voltage in the QRS complex and inversion of the T waves, and occasionally (5) roentgenographic evidence of a calcified pericardium. The heart may be normal, slightly larger, or smaller than normal in size. When a febrile illness accompanied by pericardial effusion is followed by reduction in size of the heart, and by signs of cardiac failure such as ascites, pleural effusion, and increased venous pressure, one should strongly suspect the development of constrictive pericarditis.

In the surgical correction of the disease, two points must be strongly emphasized: (1) an operative approach that permits ready access to all critical areas requiring decortication, (2) an adequate decortication of the heart, including liberation particularly of the right heart and of the inferior and superior venae cavae. Exposure of the heart through the left parasternal incision as usually practiced is considered quite inadequate, as is also the transthoracic approach through the fifth or sixth interspace. Both these incisions serve adequately for exposure of the left side of the heart, but experience indicates that it is the right side of the heart that requires the more complete decortication, and therefore a more complete exposure of this side is imperative.

Moreover, decortication of the thick-walled left ventricle is fraught with much less danger than is the removal of the pericardium over the thinned-out right ventricle and over the normally thin right auricle and the two venae

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Read at the Twenty-Ninth Annual Meeting of The American Association for Thoracic Surgery, New Orleans, La., March 29, 30, and 31, 1949.

From the Stanford University School of Medicine.

cavae. It is quite probable that inadequate exposure was a factor in some of the twenty-one recorded deaths on the operating table.

As indicated above, the pericardium over the left ventricle has not in our cases been as greatly thickened nor as "oppressive" as the pericardium over the right heart and the two caval vessels. An explanation for this may lie in the greater and more forceful pulsating action of the left ventricle which forces the irritating pericardial fluid of the preconstrictive period of effusion into the less active and more quiet areas with consequently greater inflammatory excitation of the overlying pericardium. If the strongly pulsating, highly muscular left ventricle can be hampered visibly in its activity by a constricting pericardium as seen at fluoroscopy, how much more vulnerable to such constriction would be the more easily compressible right heart and the superior and inferior venae cavae as they lie in the intrapericardial space. The effects of such compression have been studied in our experimental laboratory. Constriction of the inferior vena cava to one-half its normal caliber in a 14 kilogram dog produced a permanent ascites in approximately seven days. Constriction of the pulmonary artery to approximately one-half its normal caliber led to the development of an ascites in about seven days. Constriction of the superior vena cava alone above the azygos vein produced no trouble, but when constricted below the entrance of the azygos vein, a pleural effusion occurred on about the ninth day. This last observation suggests that the pleural effusions so commonly observed in the presence of constrictive pericarditis may not be due necessarily to compression of the left heart but to superior vena caval constriction. Even more imperative, therefore, is the need of decorticating the superior vena cava.

The thickened pericardium lying between the inferior border of the heart and the diaphragm is also a critical structure requiring excision. Probably as the result of gravity, the irritating pericardial fluid of the effusion period, which usually precedes the scarring, is directed to the bottom of the pericardial sac, thus subjecting the diaphragmatic pericardium to marked inflammation and, therefore, to marked thickening and marked subsequent contraction. This thickened pericardial sheet anchors the heart rigidly to the diaphragm, so that as the latter descends in inspiration, the heart is hampered even further by traction resulting in limitation of its filling and of its contraction. It is this increased restriction of cardiac filling and contraction due to the descent of the diaphragm to which is ascribed the momentary disappearance of the pulse, the so-called paradoxical pulse that invariably accompanies constrictive pericarditis.

The calcified and thickened pericardium on the posterior aspect of the heart cannot and need not be removed, but it is important to recognize that fibrous tissue left behind will continue to contract, that, therefore, the removal only of the easily accessible anterior pericardium is quite inadequate, and that a satisfactory pericardiectomy must include excision of the constricting envelope beyond the left cardiac border, beyond the right cardiac border, and beyond the inferior cardiac border. This *beyond the border* decortication is necessary in order that the scar that remains may not, in contracting further, enclose the heart in its grip.

It is obvious that to perform such an extensive pericardiectomy, a truly adequate exposure of the heart is necessary. This is best achieved through a limited median sternotomy from xiphisternum to the second intercostal space where a transverse incision through the sternum permits lateral displacement of the bisected sternum and the attached ribs.

The objection that in median sternotomy both thoracic cavities may be entered is no longer valid since intratracheal anesthesia is usually employed. A rent into the left pleural cavity can usually be avoided or can be closed successfully, but it is almost inevitable that the right thoracic cavity be entered if adequate liberation of the two venae cavae is to be achieved. Following careful displacement of the pleura lateralward on both sides, the pericardium is incised over the area of the left ventricle and is cautiously mobilized beyond the left border of the heart as far laterally as the left phrenic nerve (if it can be identified) which should not be injured; the pericardium over the right ventricle is then mobilized anteriorly, with excision of the pericardium overlying the pulmonary artery, the ascending aorta, and the superior vena cava. The right border of the heart is freed so as to yield a good view of the superior and inferior venae cavae. Inferiorly the heavy, frequently calcified pericardium lying between the inferior border of the heart and the diaphragm is excised from the inferior vena cava on the right border to the apex of the left ventricle on the left border. In this excision normal muscle bundles of the diaphragm should be exposed.

The right auricle must be liberated with caution if direct removal of the overlying pericardium is attempted. That its removal is possible was proved by our experiences, but if this seems too hazardous, the pericardium may be incised both along the auriculoventricular groove and at the base of the heart, leaving the intervening pericardium attached to the auricle. This has the effect of liberation and should permit the desired expansion of the auricle.

The closure of the median sternotomy is easily effected by the use of two or three No. 20 stainless steel sutures applied not to cartilage but to the bony part of the sternum, a precaution designed to avert infection in such poorly vascularized tissue as cartilage. The prepectoral fascia is mobilized on both sides for approximation in the midline with interrupted silk or cotton sutures.

We consider removal of the thoracic wall overlying the heart as unnecessary. In constrictive pericarditis the heart is limited not by the bony thorax but by the pericardium.

Because of the large area of denuded and traumatized tissue produced by pericardiectomy, sometimes performed in the presence of active tuberculous granulation tissue, there may be a considerable outpouring of wound fluid necessitating drainage of the operative site. This drainage has been effected by deliberately incising the right pleura along its mediastinal border where it has not already been opened and providing for removal of the fluid from the right chest either by repeated aspirations or by intercostal tube drainage. In the seven cases in which median sternotomy was used, complete primary healing of the operative wound has occurred, even in the presence of an active tuberculous pericarditis in four cases.

A useful tool in separating the heart from the pericardium is the so-called ''peanut'' dissector, a small round pea-sized bit of gauze in a curved clamp. By painstaking slow dissection, now blunt now sharp, the proper cleavage plane can be maintained, but it is easily lost if speed rather than safety is the watchword.

Bigger's suggestion to retain the pericardium back of the advancing edge of dissection between pericardium and myocardium may be lifesaving in case the myocardial wall is accidentally perforated, or excessive bleeding is encountered. Resuturing the liberated but still attached pericardium to the myocardial surface may effectively control such perforation or bleeding.

Selection of the optimum time for operation may be difficult, and must be determined by conditions present in the individual case. In the absence of fever, and in the presence of calcification, which in itself is evidence of a long-standing chronic state, the detrimental effects of the disease are wholly mechanical in origin and the operation may be done at any time following a period of bed rest, during which the elimination of tissue fluids is promoted by a low sodium diet and by chemically induced diuresis. Optimum nutrition with supplementary vitamins should be stressed and the thoracic and abdominal cavities should be emptied of their fluid as completely as possible by aspiration just before operation.

When the signs of compression are accompanied also by signs of acute inflammation, the problem becomes twofold: control of infection and correction of the mechanical obstruction to the normal circulation of the blood. The immediate treatment of the infection obviously requires rest in bed, optimum nutrition including supplementary vitamins, the administration of penicillin and streptomycin on the assumption of tuberculosis since tuberculosis usually cannot be proved or disproved until operation, and the correction of anemia. Improvement will be apparent from the reduction in fever, lowering of pulse rate, and decreased sedimentation rate. Operation may be delayed until such improvement is manifested, but should not be delayed long if the mechanical disturbances of compression are incapacitating and progressive. Under these conditions, the sooner the compression is corrected the better will be the ultimate results. In Case 4 only seven months elapsed from the onset of symptoms due to acute pericarditis with effusion to pericardiectomy for constricting pericardium; in Case 5, ten and one-half months elapsed. In both cases tubercle bacilli were demonstrated on culture of pericardial fluid removed at operation.

The administration of streptomycin decreases the hazard of operating in the presence of active tuberculous pericarditis. In Case 4, streptomycin was reserved for the immediate postoperative period, since this was considered the crucial period of recovery, and its administration was continued for three months after operation.

In Case 5, on the assumption of an active tuberculous pericarditis, streptomycin 1 Gm. daily, was administered from Nov. 27, 1947, to March 23, 1948. Pericardiectomy was performed May 15, 1948, and streptomycin, 2 Gm. daily, was again administered from May 10 to July 6, and 1 Gm. daily from July 6 to Aug. 10, 1948.

SUMMARY

In 265 recorded operations for constrictive pericarditis, 21 deaths occurred on the operating table, 48 deaths occurred in the early postoperative period, 118 cases were considered cured and 44 cases improved.

A satisfactory and adequate pericardiectomy must include liberation of all borders of the heart and of both venae cavae. The inferior cardiac border must be liberated by excision of the pericardium lying between the heart and the diaphragm.

Persistence of ascites following pericardiectomy is evidence of an inadequate decortication and demands reoperation and removal of more scar, rather than an omentopexy or Talma operation.

To achieve the exposure necessary for an adequate inspection and decortication of the heart, a median sternotomy with transverse division of the sternum in the second interspace is recommended. The sternum is reapproximated by several stainless steel sutures inserted through bone, not through avascular cartilage.

The wound should be drained, preferably into the right pleural space from which the fluid can be removed either by aspiration or by intercostal drainage.

In patients suspected of having tuberculosis or in those in whom evidence of active inflammation is present, the preoperative preparation should include a prolonged period of bed rest with optimum nutrition, and the administration of penicillin and streptomycin. Operation should not be deferred unduly if the symptoms of compression are incapacitating, unaffected by therapy, and progressive.

Operation was performed in nine cases: five of unknown etiology, with one death and four cures; and four of active tuberculous pericarditis, with marked improvement in all, and with probably complete cure in two.

REFERENCES

1. Heuer, G. J., and Stewart, H. J.: The Surgical Treatment of Chronic Constrictive Pericarditis, Surg., Gynec. & Obst. 68: 979, 1939.
2. Blalock, A., and Burwell, C. S.: Chronic Pericardial Disease, Report of Twenty-Eight Cases of Constrictive Pericarditis, Surg., Gynec. & Obst. 73: 433, 1941.
3. Harrington, S. W.: Chronic Constrictive Pericarditis: Partial Pericardiectomy and Epicardiolysis in Twenty-Four Cases, Ann. Surg. 120: 468, 1944.
4. Heuer, G. J., and Stewart, H. J.: The Surgical Treatment of Chronic Constrictive Pericarditis, S. Clin. North America 26: 477, 1946.
5. Sellors, T. H.: Constrictive Pericarditis, Brit. J. Surg. 33: 215, 1946.
6. Schmieden, V., and Westermann, H. H.: The Operative Management of Fibrous Constricting Pericarditis, Surgery 2: 350, 1937.
7. Graham, E., Singer, J. J., and Ballon, H. C.: Surgical Diseases of the Chest, Philadelphia, 1935, Lea & Febiger, p. 201.
8. Churchill, E. D.: Pericardial Resection in Chronic Constrictive Pericarditis, Arch. Surg. 19: 1437, 1929; Ann. Surg. 104: 516, 1936.
9. Beck, C. S., and Griswold, R. A.: Pericardiectomy in the Treatment of the Pick Syndrome, Arch. Surg. 21: 1064, 1930.

10. Friedberg, C. K.: Constrictive Pericarditis: Classic Type With Pericardiectomy, J. Mt. Sinai Hosp. 10: 717-721, 1944.
11. Hitzig, W.: Constrictive Pericarditis, an Atypical Case, J. Mt. Sinai Hosp. 10: 722, 1944.
12. Harrison, M. B., White, P. D.: Chronic Constrictive Pericarditis, a Follow-Up Study of Thirty-Seven Cases, Ann. Int. Med. 17: 790, 1942.
13. Scherf, B. L.: Cardiovascular Diseases, Philadelphia, 1947, J. B. Lippincott Company.
14. Lilienthal, H.: Thoracic Surgery, Philadelphia, 1925, W. B. Saunders Co., p. 422.
15. Roberts, J. E. H., and Wilson, J.: Pericardiectomy in a Case of Pick's Disease, Proc. Roy. Soc. Med. 29: 219, 1936.
16. Bigger, I. A.: Concretio Cordis. II. Cardiolysis for Concretio Cordis, Arch. Surg. 24: 574, 1932.
17. White, P. D.: Heart Disease, New York, 1945, The Macmillan Company.
18. Levine, S. A.: Clinical Heart Disease, Philadelphia, 1945, W. B. Saunders Company.
19. Beck, C. S.: Two Cardiac Compression Triads, J. A. M. A. 104: 714, 1935.
20. Beck, C. S.: Compression of the Heart, Radiology 37: 47, 1941.
21. Burwell, C. S.: Diseases of the Pericardium, Modern Medical Therapy in General Practice, Baltimore, 1940, Williams & Wilkins Company.
22. Holman, E.: Implantation of the Spleen in the Abdominal Wall for Portal Obstruction, A Suggested Operation for Hepatic Cirrhosis, West. J. Surg. 41: 255, 1933.
23. Ochsner, A., and Herrmann, G. R.: Experimental Surgical Relief of Experimentally Produced Pericardial Adhesions, Arch. Surg. 18: 365, 1929.
24. Trout, H. H.: The Release of Pericardial Adhesions, Arch. Surg. 23: 966, 1931.
25. Flick, J. B., and Gibbon, J. H., Jr.: Pericardiectomy for Advanced Pick's Disease, Arch. Surg. 29: 126, 1934.
26. Moore, J. A., and Murphy, J. D.: Constrictive Pericarditis With Tuberculous Intrapericardial Abscess Treated by Streptomycin, Report of a Case, Ann. Surg. 127: 685, 1948.
27. Decker, P.: Les voies d'accès à la péricardiectomie, Presse méd. 55: 59, 1947.
28. Bergouignan, M.: La pericardite constrictive, Progr. méd., Paris 6: 158, 1947.
29. Schmieden, V., and Fisher, H.: Die Herzbeutelentzündung über ihre Folgezustände, Ergebn. d. Chir. u. Orthop. 19: 98, 1926.
30. Klose, H.: Die reine Synechie und der plastische Ersatz des Herzbeutels, Arch. f. klin. Chir. 117: 138, 1921.
31. Hein, G., and Reavis, J. C.: Direct Electrocardiograms From the Human Heart in Situ. To be published.
32. Parsons, H., and Holman, E.: The Experimental Production of Ascites. To be published.
33. Gerbode, F., and Selzer, A.: Experimental Cardiac Hypertrophy, Surgery 24: 505, 1948.
34. Gerbode, F., Yee, J., and Rundle, F. F.: Experimental Vascular Anastomoses to the Heart; Their Application to Obstruction of the Superior Vena Cava, Stanford M. Bull. 6: 349, 1948.

DISCUSSION

DR. ALFRED BLALOCK, Baltimore.—Our experience confirms that of Dr. Holman. We, however, use an incision which extends from the top to the bottom of the sternum; that is, the sternum is split from the suprasternal notch to the upper abdominal region. I disagree with Dr. Holman that a Lebsche knife is an especially traumatic instrument. It is only the uppermost part of the sternum which consists of hard bone and the rest of it is split quite easily. In five consecutive cases we have used this incision and it has been our impression that the venous pressure has declined much more rapidly and the ascites has disappeared more rapidly than in previous cases in which we have used a left or right parasternal incision.

Recently we used this median sternotomy in approaching the pulmonary valve of a patient who was diagnosed as having pure pulmonic stenosis. It gives an excellent exposure of the right ventricle and of the pulmonary artery, as Dr. Holman has stated, and a good direction in which to work with a valvulotome. I do not think, however, that this incision would be very useful in an approach to the mitral valve or the aortic valve.

DR. JULIAN JOHNSON, Philadelphia.—We have used an incision that is a little different in order to obtain the same general magnitude of exposure. It is a transverse incision which extends from the midaxillary line on one side to the midaxillary line on the other.

It is made in the third or fourth interspace and divides the sternum but no ribs. By placing the rib spreader between the two ends of the sternum a wide exposure may be obtained. It has the advantage of affording excellent exposure to both sides of the heart as far around as desired.

DR. ARTHUR S. W. TOUROFF, New York.—I was very much impressed by Dr. Holman's presentation of the trans-sternal approach in cases of constrictive pericarditis. I, personally, favor a free left-sided, transpleural incision for the reason that it appears to be less traumatic and also affords a better exposure of the apex and posterior surface of the heart than the incision which Dr. Holman advocates. (Slides.) I make a submammary incision in the fifth, left, intercostal space and divide the fourth and fifth costal cartilages. By carrying the incision from the left border of the sternum well into the axilla, and retracting the edges of the wound widely, one is able to get an excellent exposure of the heart. In performing pericardiectomy through this incision, it is possible to decorticate the major portion of the anterior and diaphragmatic surfaces, the entire apex and a large part of the posterior surface. The exposure of the left lateral and posterior aspects of the heart are so complete, as to make it essential to identify and carefully retract the left phrenic nerve as it courses over the pericardium. By grasping the thickened pericardium as it is freed from the anterior surface of the heart, and making strong traction toward the left, it is surprising how far the decortication can be carried toward the right side of the heart. The best evidence of the adequacy of the approach is the fact that in none of our cases has the end result been unsatisfactory and in none has it been necessary to reoperate. I agree with Dr. Holman that decortication of the right heart is essential, for one of the most important features of constrictive pericarditis is the inability of this portion of the heart to fill adequately. As regards complete freeing of the superior and inferior venae cavae, I am not sure that it is essential. I am certain that I have not been able to do this through the incision which I have used, and yet all of our results have been excellent. Accordingly, I am inclined to the view that unless the cavae are completely occluded—which is seldom, if ever, the case—an increased rate of blood flow through the partially constricted cavae tends to compensate for the narrowed caval lumina. Under such circumstances freeing of the right heart, rather than the caval areas, has yielded entirely satisfactory results.

DR. LOUIS R. DAVIDSON, New York, N. Y.—I rise to correct an impression created by Dr. Holman to the effect that using a Lebsche knife is a dangerous procedure, by virtue of the fact that the patient is markedly shocked thereby. I am in full accord with Dr. Blalock's remarks in this connection. I have used this instrument in thirteen cases of chronic constrictive pericarditis. It has also been used in the case of myasthenia gravis and also in cases of mediastinal exploration for parathyroid tumors. In no instance has it been regretted that the Lebsche knife had been used. We are firmly convinced that it is not traumatizing. In addition, and with very little difficulty, the surgeon can curve his osseous incision.

When Dr. Holman related he took cultures from the pericardial fluid, it brought to mind that one of these thirteen patients operated upon was proved to have had actinomycosis.

I regret that Dr. Holman's customary careful technique does not permit him to use a Lebsche knife, which I have found to be a splendid instrument, particularly in this field.

DR. R. A. DORNER, Des Moines.—Dr. Holman merely mentioned the use of streptomycin in patients with tuberculous pericarditis. Years ago, as you all know, patients with tuberculous pericarditis were carried along until it was felt that the active inflammatory process had completely *subsided. In 1947 I operated upon a white man, aged 55 years, from* the medical service of Dr. Arthur Wise of the Iowa State Tuberculosis Sanatorium. This patient, with active tuberculous pericarditis, was losing ground during the "waiting period." Fluid from the pericardial sac contained tubercle bacilli; and an inoculated guinea pig was positive. The pericardiectomy was carried out through a left sternal border approach removing as much pericardium as possible. The patient improved for a time and then began to develop increasing ascites. I therefore made a right-sided incision and removed all of the pericardium from the edge of the left-sided operation down to and including the pericardium around the inferior vena cava. (From this experience I would agree thoroughly with Dr. Holman that the venae cavae should be released. One could see the blood rush into and dilate the intrapericardial portion of the cava as the pericardium was freed from around it.) I then proceeded to remove the pericardium from around the superior vena cava in a similar manner.

Streptomycin was given to this patient as follows: Preoperatively: 250,000 units every three hours the day before surgery and continued in this dosage postoperatively for three months. Five hundred thousand units were placed in the operative field.

This patient's convalescence was complicated by bilateral pleural effusions necessitating thoracenteses but these and generalized edema subsided quite rapidly after the second operation.

This patient had no evidence of tuberculosis elsewhere in the body; and under streptomycin therapy, even though there was active tuberculosis at the time of the pericardiectomies, he regained his health and at the present time appears well. I think the point should be emphasized that with streptomycin therapy patients with active tuberculous pericarditis can be operated on and, perhaps, should be operated upon quite early after onset of symptoms.

DR. CAMERON HAIGHT, Ann Arbor, Mich.—The incision which Dr. Holman has described undoubtedly gives a better exposure of the right side of the heart and the inferior vena cava than does the conventional flap incision as described by Schmieden. We have modified the latter incision, however, by extending the inferior arm laterally and have found it to be completely satisfactory. This modified incision not only gives adequate exposure of the anterior aspect of the heart, thereby allowing decortication of all of the right ventricle, but more importantly it gives an adequate exposure of the entire surface of the left ventricle, allowing the removal of the pericardial scar, and epicardial scar if present, as far posteriorly as the point of entrance of the inferior vein into the left auricle. With this incision the angle of approach to the heart is from an anterolateral direction, rather than from an anterior direction, as is the case with the flap and the sternal splitting incisions. The operation is done transpleurally.

During the last one and one-half years it has been our practice to drain the pleural space postoperatively with an airtight intercostal tube. Formerly, when using the extrapleural flap incision, the pericardial wound was drained into the pleural space by an intentional opening of the pleura before closure of the wound, and the subsequent effusion was removed by thoracentesis. If an obliterative pleuritis had occurred, the pericardial wound was drained locally with a Penrose drain. In these cases we observed a tendency for a temporary formation of new pericardial scar due to incomplete drainage of the serosanguineous effusion and a resultant fibrinous deposit on the heart. Convalescence was at times considerably delayed until the new scar had thinned. In order to minimize the tendency for the reformation of pericardial scar, we now drain the pleural cavity with an air-tight intercostal tube. Should the pleural space be obliterated by adhesions, an intrapleural pneumonolysis of the lower one-half of the lung is done, so as to form an actual space adequate for drainage. As a result of the wide decortication of both ventricles, together with the use of drainage of the pleural space, the postoperative convalescence has been more rapid than formerly, and the return of cardiac function has been uniformly better than with the previous plan of management.

DR. EDWARD D. CHURCHILL, Boston.—It is of interest that at the time Dr. Holman has been moving toward the right, my own position has been shifting to the left. And somewhat paradoxically, if the politically derived metaphor is continued, I have become less radical while doing so. The impediment to the action of the heart caused by constrictive pericarditis seems to me to center in the restriction of ventricular action, and distortion of auriculoventricular channels. This change in emphasis has been based on the careful observation of patients that have not been totally relieved by the operation shown by Dr. Holman. Studies with cardiac catheterization have pointed toward difficulty on the left side of the heart; consequently we have made a more determined effort at the initial operation to expose fully this area. The phrenic nerve is identified, dissected from the pericardium, and suspended so that one may work under it. The dissection is carried back along the left auriculoventricular groove. The entrance of the pulmonary veins into the left auricle is exposed and liberated. I believe this is a crucial area because residual scarring at that point may simulate advanced mitral stenosis.

DR. J. R. HEAD, Chicago.—Of the thirteen patients who underwent surgery at Hines Hospital, there was a striking difference in the operative results when one compared the patients resected early against those resected late in the course of the disease. In the group of advanced cases, five patients were operated on, three showed moderate improvement, one showed no improvement, and there was one immediate postoperative death. In contrast, there were eight cases resected in the less advanced group with excellent results in all. This emphasizes the desirability of early operative intervention. In the far advanced cases, we have often found spicules of calcium with mushroomlike ends invading the myocardium and making its removal from this already weakened muscle very risky if not impossible.

The problem of contacting patients during the early phase of the disease is obviously difficult. The diagnosis of acute pericarditis is frequently overlooked and the patient may be relatively asymptomatic until the terminal stages of the constriction. Because of the good results with surgery early in the disease, Dr. Lyle Baker, Chief of Medicine, has established the policy of careful follow-up studies in all cases of acute pericarditis. If with the absorption of the effusion and return of the heart size to normal there is decreased pulsation on fluoroscopy and associated with this an increasing venous pressure and circulation time, it is then apparent that compression is taking place. If this compression continues to progress after a period of observation, operation is indicated providing the disease is stabilized as indicated by the patient's temperature and sedimentation rate. Antibiotics have helped to shorten this stabilization time and allow these patients to come to surgery at an even earlier and more advantageous stage of the disease. While only comparatively few patients who suffer from acute pericarditis will develop chronic compression, it is urged that they be followed closely and operated on early when evidence of progressive compression is confirmed.

DR. E. E. AVERY, Chicago.—The etiology of one of our cases of acute constrictive pericarditis with resection at Hines Hospital proved to be an organized hemopericardium. This young Negro man suffered a stab wound of the heart, and when first seen had an obvious cardiac tamponade. The heart size gradually returned to normal size but there was a progressive decrease in cardiac pulsation on fluoroscopy with increasing venous pressure and circulation time. Although we could find no reference to this condition, we felt that the pathogenesis was probably analogous to that of an organizing hemothorax, as has been so well described by Langston, Tuttle, and Samson. With this similarity in mind, two months were allowed to pass before pericardiectomy was done so that the clot would have sufficient time to organize and thereby facilitate decortication. At surgery the thickened pericardium with an adherent organized clot was resected. The epicardium was also covered with an organized fibrinous clot approximately one centimeter in thickness. A plane of cleavage was developed and the clot was easily stripped from the heart with gentle dissection. We do not know how often this situation may occur in hemopericardium, but we do feel that these cases should be carefully followed for evidence of progressive compression, and that the optimum time for decortication is probably six to ten weeks, at which time the clot is not densely adherent but is sufficiently firm to peel easily.

DR. HOLMAN.—The approach through the left thoracic cage seems to me to have certain inherent dangers of not exposing that portion of the heart which is most vulnerable to trauma and to accidental tears while freeing the pericardium from the right side of the heart, which I believe we all agree must be liberally decorticated. Accordingly, I would be very hesitant to use an approach that does not give good access to the right auricle as well as the right ventricle.

I think most writers are agreed that it is the inflow to the heart that is most impeded by constrictive pericarditis rather than the outflow, and it is the obstruction to inflow to which we ascribe the predominant symptoms of effusion, ascites, and peripheral edema, hence, the greater need of liberating the venae cavae and the right heart.

A METHOD FOR EXPOSURE OF THE CARDIAC SEPTA

An Experimental Study

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Detroit, Mich.

Many investigators have successfully created defects of the cardiac septa. In more recent years, these have been done chiefly by Cohn,[1] Murray,[2] Martin, Essex, Burchell, and Edwards,[3] as well as by Blakemore,[4] Blalock and Hanlon,[5] and others. With the exception of the method of Blalock and Hanlon, these have been punch wounds or stab wounds of the septa produced blindly. These latter authors excised a portion of the posterior margin of the interatrial septum under direct vision.

An instrument has been devised by which the right side of the heart, either the right atrium or the right ventricle, may be opened and the septum exposed for varying lengths of time. The size of this exposure varies according to the instrument used and to the size of the heart to which it is applied. The septum, either the interatrial or the interventricular, may be exposed over a distance of 2 to 2.5 cm. in diameter. Various technical procedures can be carried out on the septa under direct vision. The incision in the right side of the heart is then closed.

Reference has been made in the literature to the interatrial septum being somewhat horizontally placed.[6] In fact, this has been given as the reason why the blood flow is from left to right in interatrial defects, the left antrium said to be superimposed or superior to the right. By more recent examination of the cardiac dynamics, especially by venous catheterization, it has been found that the actual pressure in the left atrium is greater than that in the right, which accounts for the left to right flow. In the dog, the right atrium is actually a little higher than the left.

The instrument consists of a double ring structure. The proximal ring is a large one, two to three inches in diameter, while the distal rings, which are placed at right angles to the former, are from 1.7 cm. up to 2.5 cm. in size (Fig. 1). The distal rings can be varied in size according to the size of the heart to which it is applied. Inasmuch as the right side of the heart, especilly the right atrium, is slightly larger than the left, the ring of the clamp which is to be applied to the left side of the heart may be slightly smaller than the right, thereby producing less obstruction to the circulation on the left side of the heart.

EXPOSURE OF INTERATRIAL SEPTUM

In the application to the atria, the large proximal ring encircles the base of the heart and the outflow tracks, while the distal rings approximate the lateral walls of both atria against the septum (Fig. 2). When the clamp is in place, there is no obstruction to the outflow of the ventricles. There is sufficient space around the distal rings when applied to the atria to permit blood to reach the

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Read at the Twenty-Ninth Annual Meeting of The American Association for Thoracic Surgery, New Orleans, March 29, 30, and 31, 1949.

From the Research Division of Harper Hospital.

ventricles. Within the circle of the ring which collapses the atria, a vertical incision is made in the right atrial wall as large as the ring of the clamp permits. After the right atrial wall has been incised, a few interrupted sutures are placed in the edges of the incision for later closure. These sutures are placed at this time so that, if the heart shows signs of failure, they can be pulled up and the clamp released, thereby resting the heart and allowing it to regain its full function. The clamp is then reapplied over the incision. Upon incising the right atrial wall, the interatrial septum is in view throughout the circumference of the ring (Fig. 2, inset *a* and *b*). In the application of the clamp to the atria, the lateral wall of the left atrium is situated far posteriorly and the septum lies directly beneath the right atrium. One limb of the clamp, therefore, completely encircles the base of the heart and comes to rest to the right side of the outflow tracts. When the clamp is in place, obviously there is some obstruction to the atrial blood flow, but this is not sufficient to interfere seriously with the cardiac output for short intervals.

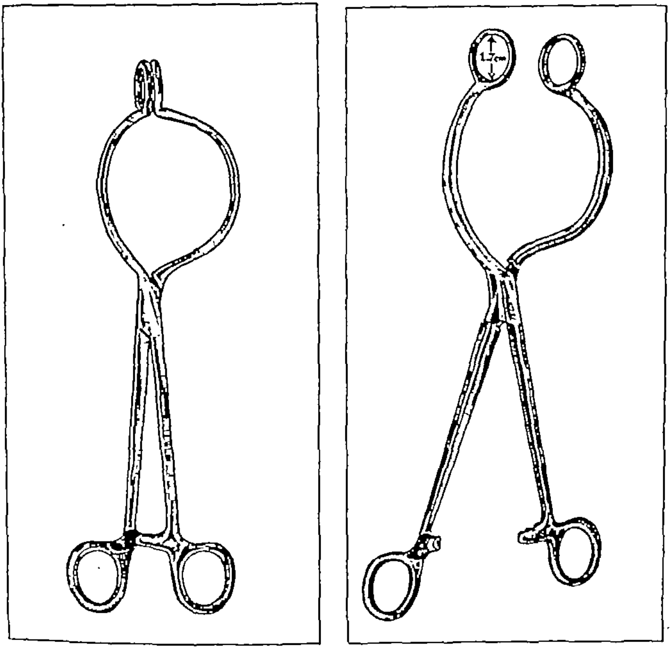

Fig. 1.—The instrument used for exposure of the cardiac septa.

The dogs have been anesthetized with procaine solution intravenously. After the heart has been exposed, it has been further anesthetized with procaine solution topically. When the instrument is slowly but progressively applied to the atria, there may be some slight conduction disturbances which seem to disappear after the clamp is once firmly in place. During the remainder of the time the clamp is applied to the atria, the heart is regular in rhythm. Too quick a clamping of the atria or too rapid a release of the clamp sets up conduction disturbances which soon right themselves. The length of time which the heart will withstand the clamp in place varies considerably. Some animals have withstood the clamp in place for thirty minutes, at the end of which time there was no sign of cardiac weakness or failure. Other hearts have withstood the clamp only a few minutes, perhaps three to five minutes, when they showed evidence of failure and the clamp had to be released. If the clamp remains on after there are signs of poor heart function, the ventricles eventually go into fibrillation and the heart dies. Apparently the reason that some hearts have withstood the clamp in place for so long a time is because of the size of the heart

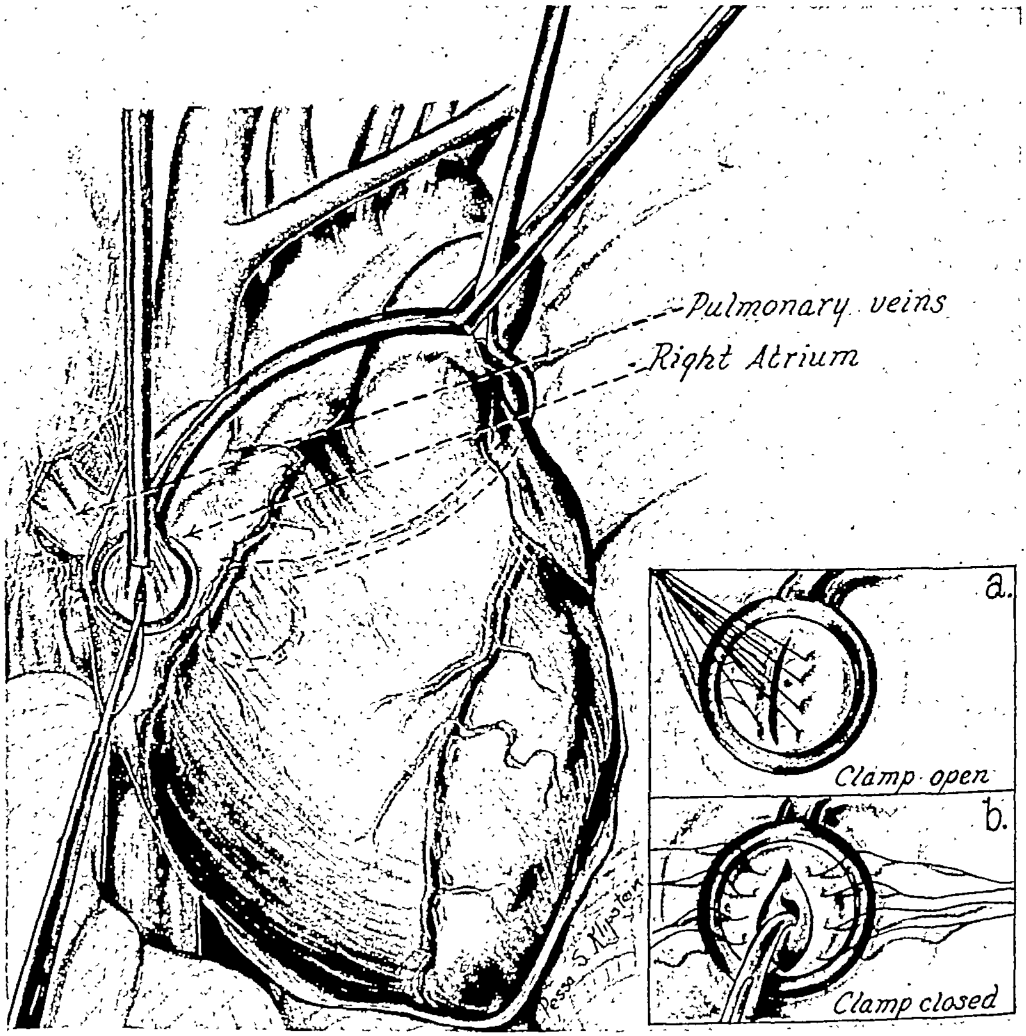

Fig. 2.—Showing instrument applied to atria. Inset *a* shows sutures in place and clamp released. Inset *b* shows clamp reapplied and defect of interatrial septum being made.

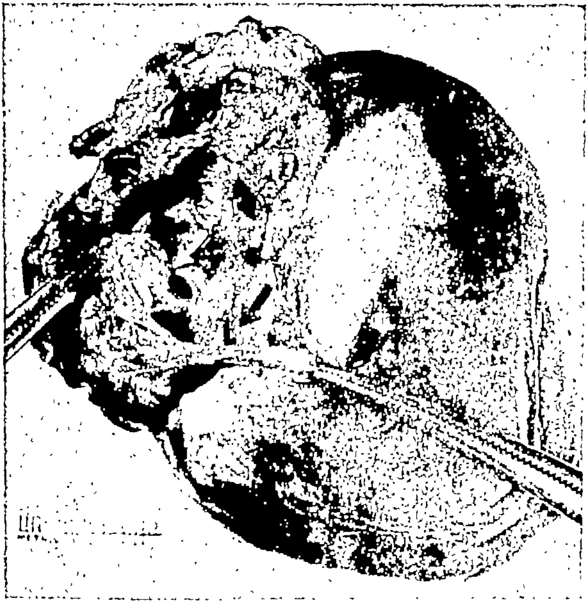

Fig. 3.—The right atrial wall has been excised. The dark arrow points to the coronary sinus, the light arrow points to the defect created. One month after operation.

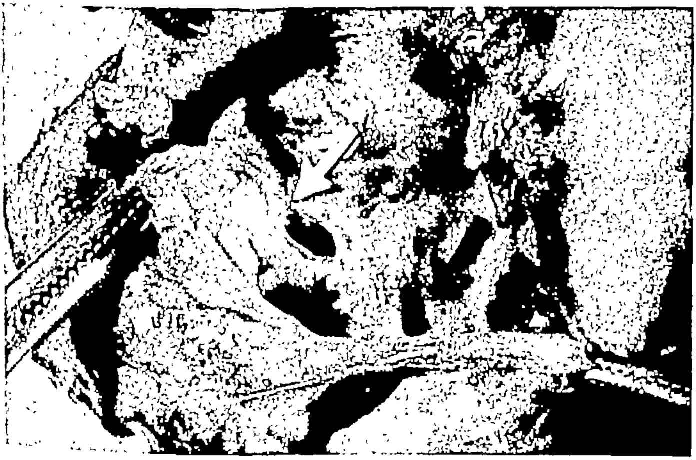

Fig. 4.—High power view of Fig. 3 showing defect of interatrial septum. One month after operation.

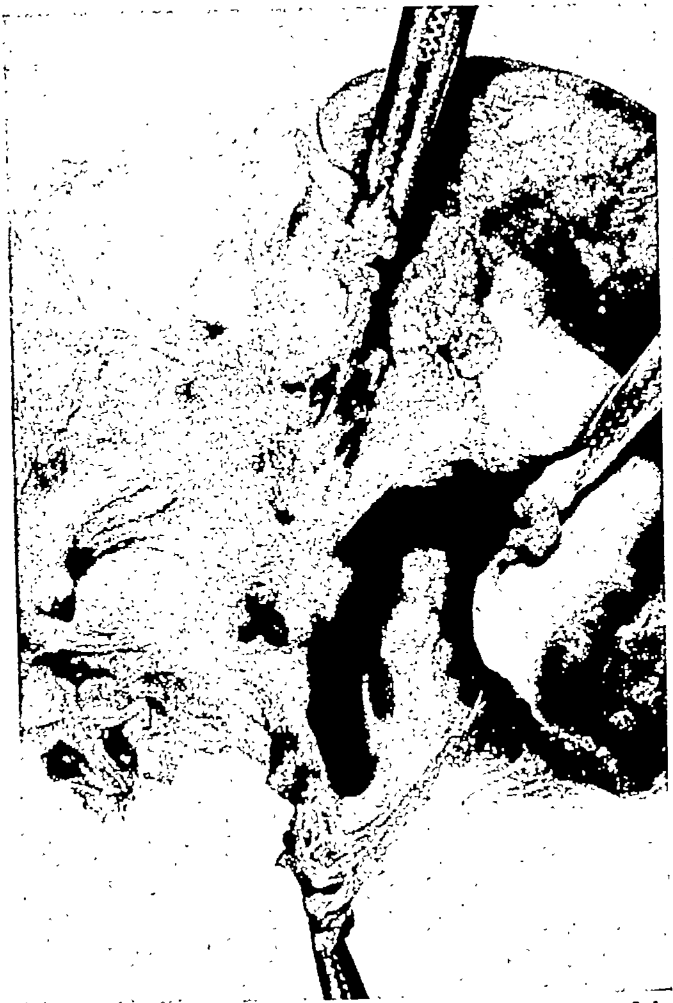

Fig. 5.—The right atrial wall has been removed. The sutured and healed defect of the interatrial septum is shown. There is some distortion of the septum due to the closure of the defect. One month after operation.

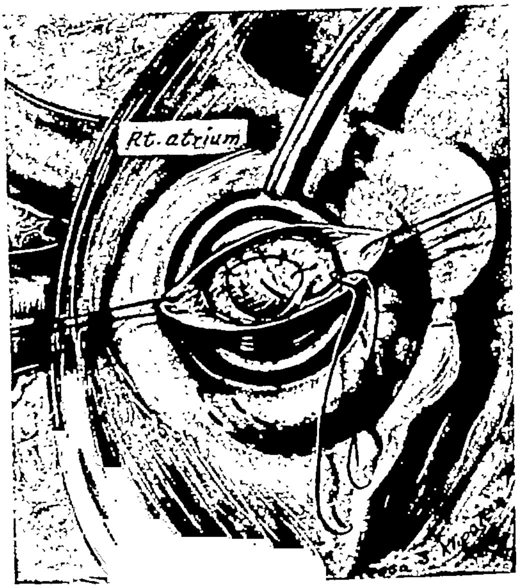

Fig. 6.—Showing method of suturing large defect of interatrial septum to left artial wall. The instrument is closed.

in relation to the size of the rings of the clamp. By using larger animals larger than thirty pounds in weight, the results are much better and only occasionally is the animal lost.

By this method which I have used, a portion of the atrial septum, up to 2.5 cm. in diameter, can be completely exposed on its right surface. Defects, or communications with the left atrium, can be made under direct vision of a known and desired size, up to 2.5 cm. in diameter (Figs. 3 and 4). Obviously, a defect of 2.5 cm. in the dog's interatrial septum constitutes almost a total excision. The resulting defect can be closed by the use of a continuous silk suture (Fig. 5). In some instances, where the defect created was larger, it was closed by suturing the edge of the defect to the left atrial wall (Fig. 6).

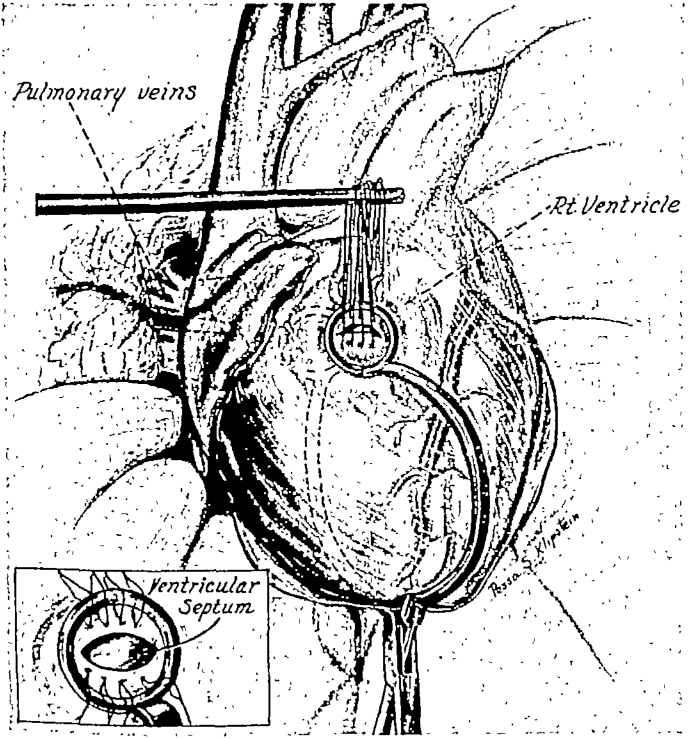

Fig. 7.—Showing instrument applied to ventricles with closure sutures in place.

According to Templeton and Gibbon,[7] the superior and inferior venae cavae may be completely occluded for as long as nine minutes and have the animal

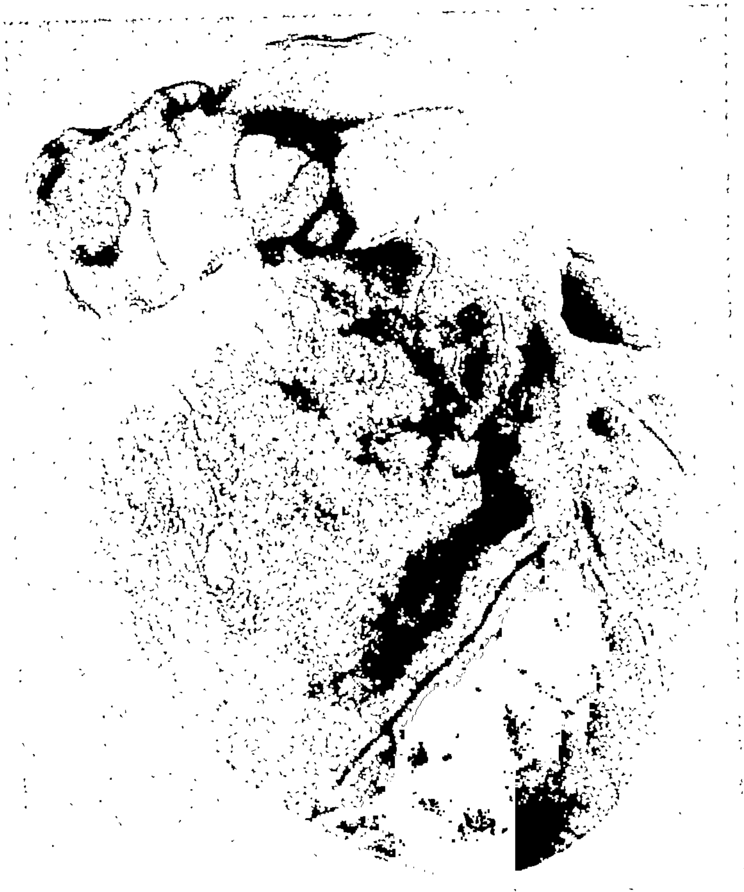

Fig. 8.

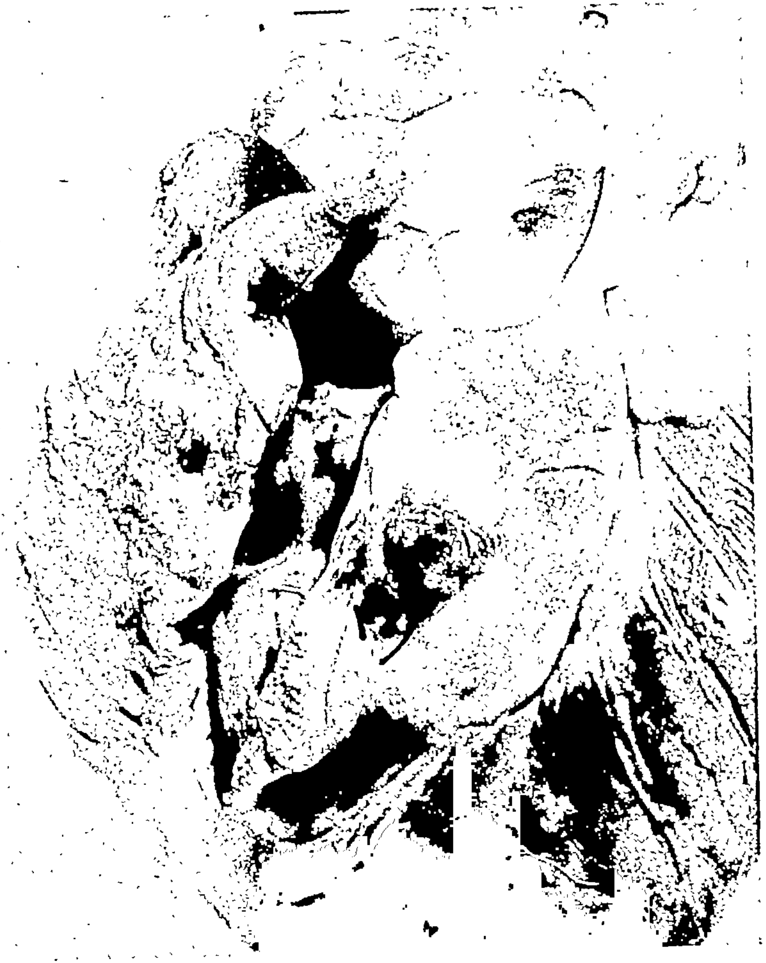

Fig. 9.

Fig. 8.—The incision in the right ventricular wall is healed. One month after operation.

Fig. 9.—The healed right ventricular incision has been opened. The buried silk sutures are seen in the septum. One month after operation.

survive. While the instrument applied to the atria may decrease the amount of blood reaching the ventricles, there is no visible dilatation of the venae cavae present. After the heart has been totally exposed, a defect in the interatrial septum can be palpated by placing the index fingers on each atrial wall and compressing them against the septum.

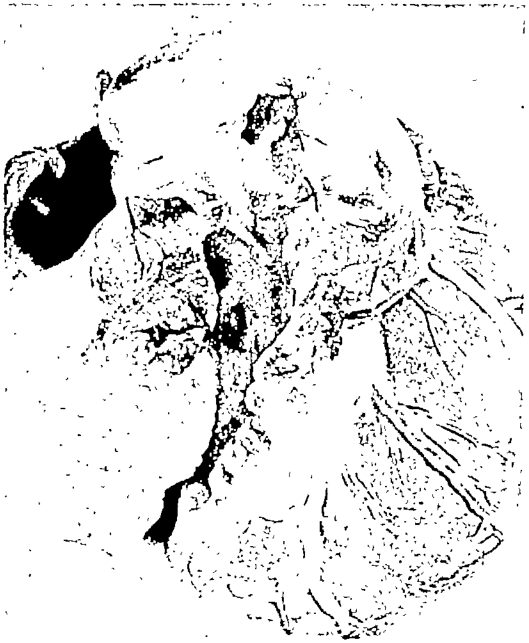

Fig. 10.—A buried silk suture is seen in the pulmonary valve. One month after operation.

EXPOSURE OF INTERVENTRICULAR SEPTUM

In the application of the instrument to the ventricles, the left ventricular or posterior wall is collapsed against the septum, while the anterior or right ventricular wall is compressed against the anterior wall of the septum (Fig. 7). A transverse incision is then made within the ring of the clamp through the right ventricular wall. The septum is exposed immediately beneath the ventricular wall. Inasmuch as the ventricular septum in the dog is composed of thick musculature, similar to the ventricular wall, it is sometimes difficult to know when one has incised all the way through the ventricular wall. After the ventricular septum is exposed, two or three interrupted silk sutures may be placed in the septum and the incision closed (Figs. 8 and 9). Also a defect in the septum may be created under direct vision. It has been possible to expose the septum high up near the pulmonary valve. In fact, in one instance, it was possible to place a suture in the middle pulmonary valve cusp (Fig. 10). The duration in which the instrument can be kept in place is comparatively short, not over three or four minutes. Some of the difficulty has been in the fact that the clamp may occlude the left coronary artery. Perhaps, by varying the size and shape of the posterior limb of the clamp and with some supplemental method of oxygenation during the procedure, the instrument can be applied for longer periods of time.

Approximately fifty operations have been done. During the early part of the period the mortality rate was approximately fifty per cent. However, with experience and practice, it is now possible to expose either the interatrial or the interventricular septum with only an occasional death of the animal. This is particularly true in dealing with the interatrial septum since the instrument may be released at any time.

REFERENCES

1. Cohn, Roy: Experimental Method of Closure of Interauricular Septal Defects in Dogs, Am. Heart J. 33: 453, 1947.
2. Murray, Gordon: Closure of Defects in Cardiac Septa, Ann. Surg. 128: 843, 1948.
3. Martin, W. B., Essex, H. E., Burchell, H. B., and Edwards, J.: Forum on Fundamental Surgical Problems, American College of Surgeons, Los Angeles Meeting, 1948.
4. Blakemore, Arthur H.: Discussion, Paper by Murray: Closure of Defects in Cardiac Septum.
5. Blalock, Alfred, and Hanlon, C. Rollins: Interatrial Septal Defects—Its Experimental Production Under Direct Vision Without Interruption of the Circulation, Surg., Gynec. & Obst. 87: 183, 1948.
6. Uhley, M. H.: Lutembacher's Syndrome and a New Concept of the Dynamics of Interatrial Septal Defects, Am. Heart J. 24: 315, 1942.
7. Templeton, John Y. III, and Gibbon, John H.: Experimental Reconstruction of Cardiac Valves by Venous and Pericardial Graphs, Ann. Surg. 129: 161, 1949.

(See discussion on page 672.)

THE CHOICE OF THE SIDE FOR APPROACH IN OPERATIONS FOR PULMONARY STENOSIS

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BLALOCK on Nov. 29, 1944, operated on a 15-month-old blue baby and created an anastomosis between the left subclavian and pulmonary arteries. The operation was successful in increasing the quantity of blood flowing through the infant's lungs and in a short time other children suffering from pulmonary stenosis were given similar surgical treatment. Four years later, he was able to report and analyze the results of over 600 operations.[2] At first, it was thought that the systemic-pulmonary shunt could be safely accomplished with the use of any of the larger vessels in the region of the aortic arch, namely, the two subclavians, the innominate, and the left common carotid arteries. However, the incidence of cerebral damage soon narrowed the choice to the two subclavians and, furthermore, Blalock early expressed a strong preference for one particular subclavian, that which comes off the innominate artery rather than off the aorta itself, because of the more favorable angle formed with the parent vessel after the rotation downward toward the pulmonary artery.

A method of producing the shunt without using any of the arterial branches became available when Potts and his associates[3] devised the aortic clamp which permits the creation of a direct aortic-pulmonary anastomosis without even temporary complete occlusion of the thoracic aorta.

When the surgeon is asked to operate on one of these patients, his pediatric colleagues will inform him of the position of the aortic arch (it is inclined toward the right in a fourth of the cases) and whether or not there is dextrocardia (not rare in this group). He then has to decide whether a Blalock or Potts type of procedure is indicated, and if the former, which side of the chest should be entered. It is not presumed that this communication will give the final answer to these questions, but it will present our personal experience in 50 operations and will show how we have arrived at a simple rule for resolving the problem of the side for operative approach in the individual case.

The fifty operations were carried out on forty-nine patients with pulmonary stenosis or atresia. All of the patients were examined preoperatively by Dr. Robert Ziegler and Dr. Mason Sones of the Division of Pediatric Cardiology. It is to their credit that every patient operated on was found to have a definite deficiency in pulmonary circulation. They have also rendered yeoman service in the matter of postoperative care. Our failures have been due to technical errors in the operating room or grossly unfavorable anatomic situations.

Blalock operations were planned for thirty-five of the fifty patients. With two exceptions, the age range was from 2 to 24 years. Fifteen were over 12 years of age. There were five failures to complete the operation. A girl, aged 15 months, was found to have the pulmonary arterial tree represented only by tiny branches to the upper pulmonary lobes, a condition verified at autopsy.

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Read at the Twenty-Ninth Annual Meeting of the American Association for Thoracic Surgery, New Orleans, La., March 29, 30, 31, 1949.

A girl of 20 months showed no vestige of a pulmonary artery at operation and post-mortem examination revealed that life had been maintained by blood which reached the lungs through dilated bronchial arteries. A third patient expired on the operating table after the operation had been discontinued because of spells of bradycardia approaching asystole which occurred every time the right pulmonary artery was manipulated. This was the only death in the operating room.

The other two operations were not completed because the right subclavian artery which arose from the innominate could not be approximated to the pulmonary artery so that an anastomosis could be made. Following are reports of these two cases.

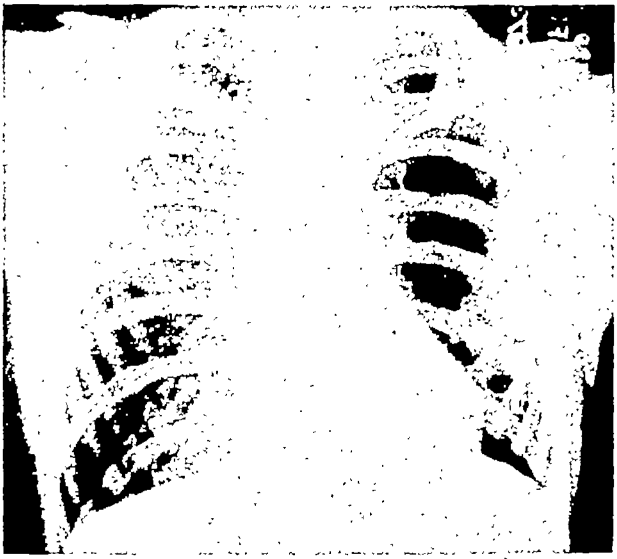

Fig. 1.—Roentgenograms of the chest, Case 2, showing the very high aortic arch. Neither subclavian artery could be approximated to a pulmonary artery.

Case 1.—T. G. was a moderately cyanotic girl of 11 years, rather tall for her age. The aortic arch was on the left. On Sept. 10, 1946, the right chest was entered through the third interspace anteriorly. A fair sized, but thin pulmonary artery was available. The right subclavian artery was isolated in the superior mediastinum with considerable difficulty due partly to poor exposure through the third interspace incision. It was ligated and divided at as high a level as was practical. It could not be approximated to the pulmonary artery until the carotid artery was divided between ligatures so that the length of the innominate could be added to that of the subclavian. Even then the tension on the structures was such that after the placement of the posterior suture line, a small movement of the mediastinum or perhaps an assistant's hand resulted in a disruption of the suture line. After a futile attempt at end-to-end anastomosis the chest was closed with the following vessels divided between ligatures: right common carotid, right subclavian and right pulmonary arteries. The patient recovered consciousness, but became hemiplegic the next day and expired a week later. It is probable that an approach on the left side would have met with more success. Since that early experience, we have not interfered with the circulation to the brain by ligating the carotid or innominate arteries.

Case 2.—J. F., a boy aged 13 years, had a left aortic arch. On May 17, 1948, the right subclavian artery was ligated and divided high in the apex of the chest. It could not be approximated to the side of the pulmonary artery. An attempt was made to make an *anastomosis with the proximal end of the divided arterial branch to the upper lobe,* but because of tension on the structures a functioning shunt could not be formed. The subclavian artery was ligated near the innominate and the chest was closed. He survived the exploration and five months later he was operated on again. A left subclavian-pulmonary anastomosis had been planned. It was found that the aortic arch was extremely high in the chest, a fact which should have been obvious from a glance at the x-ray picture (Fig. 1). The short length of subclavian artery available on this side was totally inadequate *to reach the pulmonary and not even a Potts procedure appeared to be feasible* because the arch of the aorta was at least three fingerbreaths away from the pulmonary

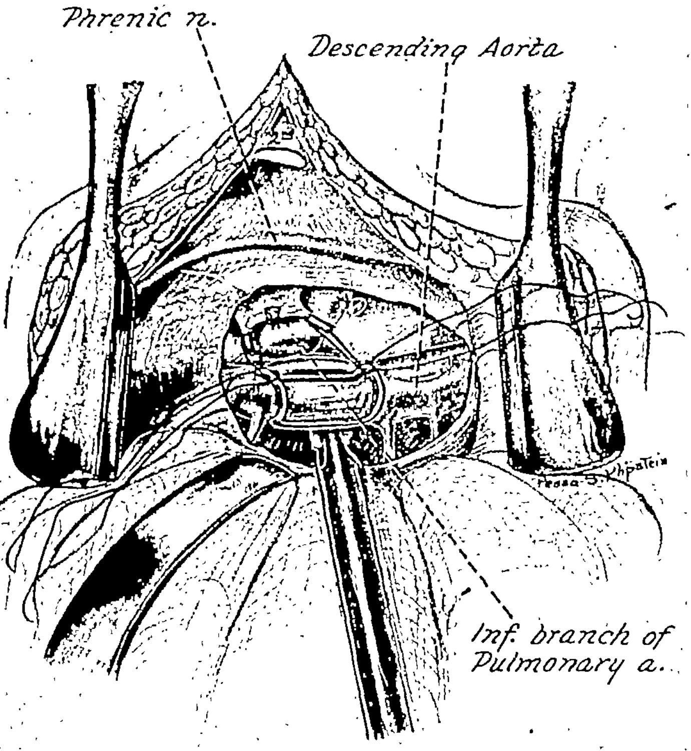

Fig. 2.—Operative procedure eventually carried out in Case 2. An anastomosis was created between the inferior branch of the pulmonary artery and the descending aorta with the aid of a large Potts-Smith clamp.

artery. We considered using the internal mammary artery in some way, but fortunately a better solution was at hand. The descending portion of the pulmonary artery, distal to the origin of the large branch *to the upper lobe, was dissected out of the lung substance* and with the use of an extra large Potts-Smith clamp which had been made for use in operations *for* coarctation, a satisfactory direct aortic-pulmonary anastomosis was performed (Fig. 2). It was necessary to ligate and divide the branch to the upper lobe in order to obtain sufficient exposure of the descending branch. The boy now has a loud ductus murmur in the left lung field and the functional result has been as good as any in the series. It is obvious that an approach from the left in the first instance would have saved him one hazardous operation. The availability of an assortment of Potts-Smith clamps should make it possible to make some sort of a shunt in all cases with a pulmonary artery without dependence on the capricious subclavian artery.

There were two other instances of marked technical difficulty due to the short length of the subclavian artery coming off the innominate. Satisfactorily functioning anastomoses were finally made, but the patients expired on the day of operation due to hemorrhage from points other than the suture lines.

CASE 3.—A. S. was a woman aged 22 years. A left-subclavian pulmonary anastomosis had been made elsewhere on Oct. 28, 1946. Apparently this had not functioned since operation, presumably because of the kinking due to the unfavorable angle. On April 21, 1948, the right chest was opened and the subclavian artery was mobilized and divided as far distally as possible. The pulmonary artery was very thoroughly mobilized and by pulling it up into the mediastinum until it was V-shaped, it was possible to approximate it to the end of the short subclavian, to which marked traction was applied. During the construction of the anastomosis, we were bothered continually with slipping of the bulldog clamp on the subclavian and it was necessary to reapply it four times. Traction on the holding sutures attached to the clamp did not hold the artery steady enough and an assistant was forced to grasp it with a Kelly clamp. Unfortunately during at least a part of the procedure, this clamp became locked over the two jaws of the bulldog clamp. After the completion of the anastomosis, there was no leak in the suture line when the pulmonary constrictors were released, but when the bulldog clamp was removed, there was brisk hemorrhage from a longitudinal slit in the subclavian artery. This injury was obviously where the arterial wall had been fractured by the tightly applied bulldog clamp. The defect was repaired by suture, after which the operation was considered to be a success and the chest was closed. Her color was remarkably improved. During the evening, the blood pressure was observed by means of a cuff applied to the lower extremity, since by this time both subclavians had been ligated. This pressure rose from 220 mm. to 260 mm. of mercury. Still nothing happened until she vomited. She then became pulseless and expired. Autopsy showed a new longitudinal rupture in the subclavian artery, obviously the companion injury to the one which had been repaired at the operation. Assuming that the postoperative hypertension and vomiting were inevitable, the fatal outcome probably could have been prevented by buttressing the injured artery with Gelfoam by the method of Jenkins.[4] There might have been less tension if the distal end of the divided pulmonary artery had been used for the anastomosis.

CASE 4.—M. T. was a 13-year-old girl with a left arch. On April 26, 1948, she was operated on from the right side. The subclavian artery was very short and we anticipated some of the kind of trouble which had been encountered five days before in patient A. S. No branch of the artery was visible and after rather marked traction was put on it to obtain length, a single simple ligature was tied as far distally as possible. With the purpose of saving all available length, the vessel was transected rather close to the ligature. The ligature came away in the operator's hand. There was a brisk flow of blood from the apex of the chest which was controlled by gauze packing. Before blood replacement was complete, there was a period of hypotension (60 mm. mercury systolic) during which time the packing was removed without recurrence of bleeding. Attempts were made to pick up the end of the vessel with a clamp, and one or two sutures were placed blindly in the general area, but it was presumed that the vessel was still insecurely ligated. It was decided that a reasonable procedure would be to pack the neck from below with Gelfoam, close the pleura tightly by suture and proceed with the anastomosis. It was believed that normal blood pressure would be achieved before the chest was closed and thus the hemostasis would receive a physiologic test. A moderately satisfactory anastomosis was formed between the end of the subclavian artery and what was thought to be the main pulmonary artery. The blood pressure by this time was 100/60 and there was no sign of hemorrhage from the apex of the chest, therefore, the lung was expanded and the incision closed. Several hours after the operation, Dr. Ziegler became alarmed because he could feel a pulse in the right wrist. His fears were well founded, because a short time later the patient expired suddenly and autopsy showed a massive right hemothorax. The subclavian vessel had been cut flush with the common level of origin of the vertebral artery and thyrocervical trunk. A soft thrombus had been blown out by the increase in blood pressure. The examination also revealed that there was early branching of the pulmonary artery and only the superior branch had been exposed and utilized for the deficient anastomosis. In retrospect, the fatal outcome could have been avoided by using a transfixion ligature on the distal end of the cut subclavian even though it meant losing a few millimeters of length, or, after the slipping of the ligature, the open vessel should have been adequately exposed and ligated after splitting the sternum from the second interspace upward.

CASE 5.—Following these two fatalities, the next patient to be operated on was a girl of 13 years, S. T., with a left arch. The right approach was used again. A large vertebral artery came off the subclavian early, and the continuing artery was not of good caliber. An attempt was made to use the divided proximal end of the upper pulmonary branch, but the anastomosis appeared to be carrying a grossly inadequate quantity of blood and it was excised. The suturing for an end-to-side anastomosis was completed twice, using the part of the artery distal to the vertebral branching, but it was obvious that an insufficient shunt had been created. After extreme mobilization of the carotid and pulmonary arteries, we were able to make a large end-to-side anastomosis after sacrificing all of the subclavian artery distal to vertebral. It is a tribute to the anesthetist that his patient recovered consciousness following a long period of anesthesia, and made an uneventful recovery, being completely relieved of her previous incapacity.

It is understandable that after the experiences just related, we were extremely interested to hear the presentation of Holman[3] at the Quebec meeting of the American Association for Thoracic Surgery in June, 1948, in which he stated that the left subclavian artery had been deliberately chosen in preference to the right in twenty-three cases. In his discussion of this paper, Blalock said that he, too, would choose the left subclavian artery if the subject were over 12 years of age or over 5 feet in height. All of the five cases mentioned above come in that category. However, our experience with the right subclavian artery in the borderline group of cases had been so distressing that we decided to follow the suggestion of Holman and use the left subclavian in all cases in which the Blalock procedure was planned, regardless of the age of the patient. In this connection, it will be remembered that there has been unanimous agreement that if there is a right aortic arch, the left approach will be used with satisfaction because one has the advantage of a fairly long subclavian artery with its favorable angle with the innominate as well as the longer and more mobile pulmonary artery.

Thus far, mention has been made of only one of the factors which contributes to the difficulties of a right subclavian-pulmonary anastomosis, namely, the shortness of that subclavian artery. There are other anatomic peculiarities which make the right-sided operation hard. Fig. 3 shows what is seen in the average case after beginning the dissection of the pulmonary artery. Only the superior branch of the artery is visible. After division of the azygos vein and retraction of the vena cava, the main trunk becomes evident, but too often the inferior branch comes off quite proximally, with the result that there is little length of the main trunk available for an end-to-side anastomosis, and the inferior branch tends to prevent the artery from being dislocated upward, a maneuver which is essential. Even after the vena cava has been mobilized and retracted anteriorly and medially, the systemic vessel to be used is not visible, except occasionally in the extreme apex of the chest. It seems to lie in a separate fascial compartment in the mediastinum and is reached only by sharp dissection through tissues which may bleed in a troublesome way. A small branch torn off inadvertently is followed by brisk hemorrhage which tends to convert the operative area into a large mediastinal hematoma. The recurrent nerve prevents free mobilization of the vessel before the latter has been ligated and divided.

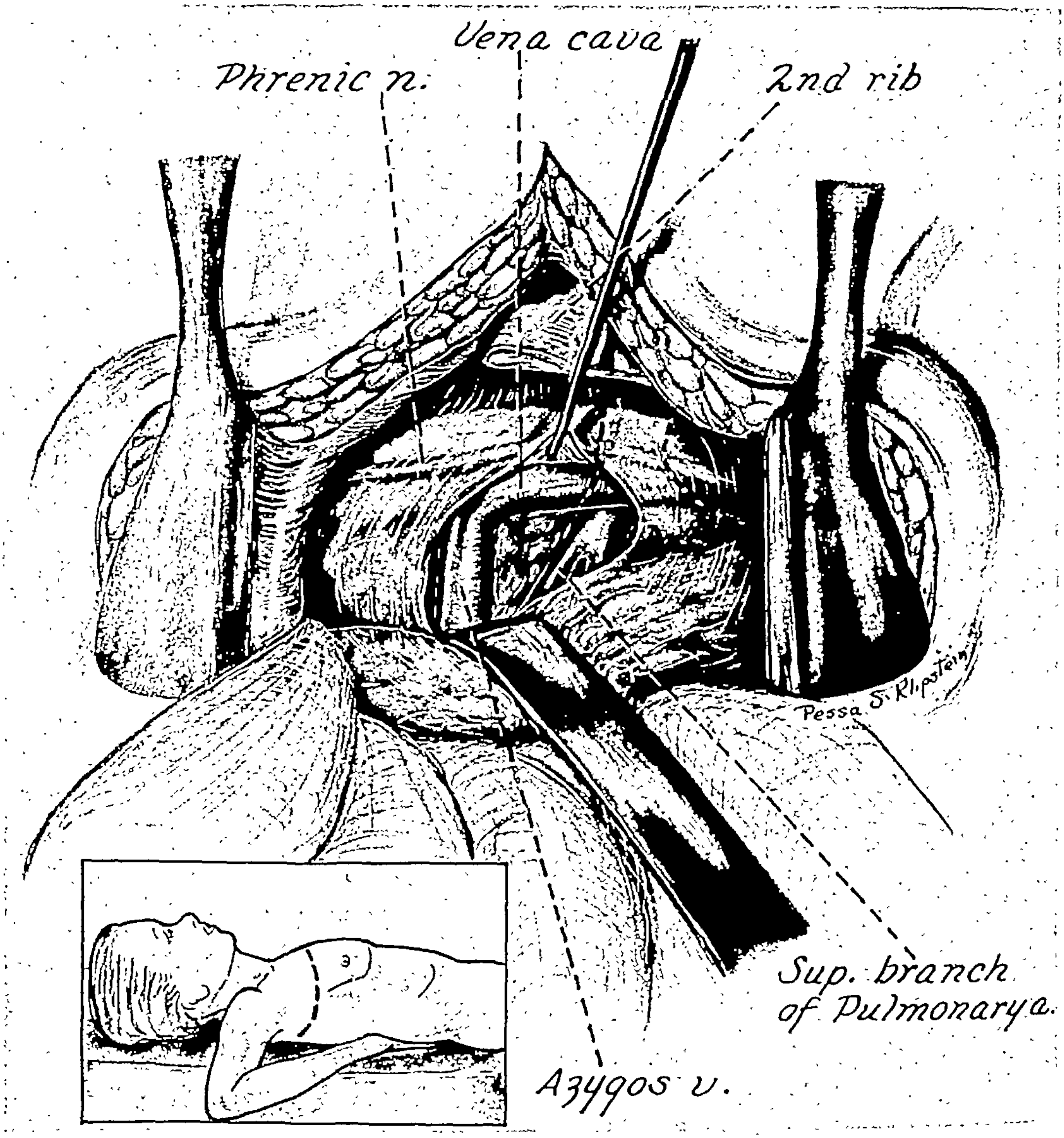

Fig. 3.—Structures seen at the beginning of the dissection to expose the right pulmonary artery. The main trunk of the artery and the inferior branch lying behind the vena cava and right auricle are indicated by dotted lines. The azygos vein must be cut and extensive dissection carried out behind the vena cava to expose the subclavian artery.

In contradistinction, on the left side (if the arch is on the left), in almost every case one sees the two structures which are to be joined as soon as the rib spreaders are applied and the upper lobe of the lung is retracted downward and laterally (Fig. 4). The pulmonary artery and subclavian artery lie just beneath the pleura. When the pleura is cut, it retracts because of its own elasticity, and leaves an assistant's hand free which would be utilized in retracting the vena cava if the incision had been on the right. The recurrent nerve passes back of the aorta itself and neither it nor the vagus are close enough to the subclavian artery to be in danger when that vessel is mobilized. A relatively long segment of the main trunk of the pulmonary artery is available for the anastomosis. After mobilization, it can be brought quite high in the chest to meet the systemic vessel (Fig. 5). If the opening in the pulmonary artery is placed far laterally on the vessel, the subclavian artery is not caused to bend so acutely over th aorta, and the length of the pulmonary proximal to the anastomosis is increased

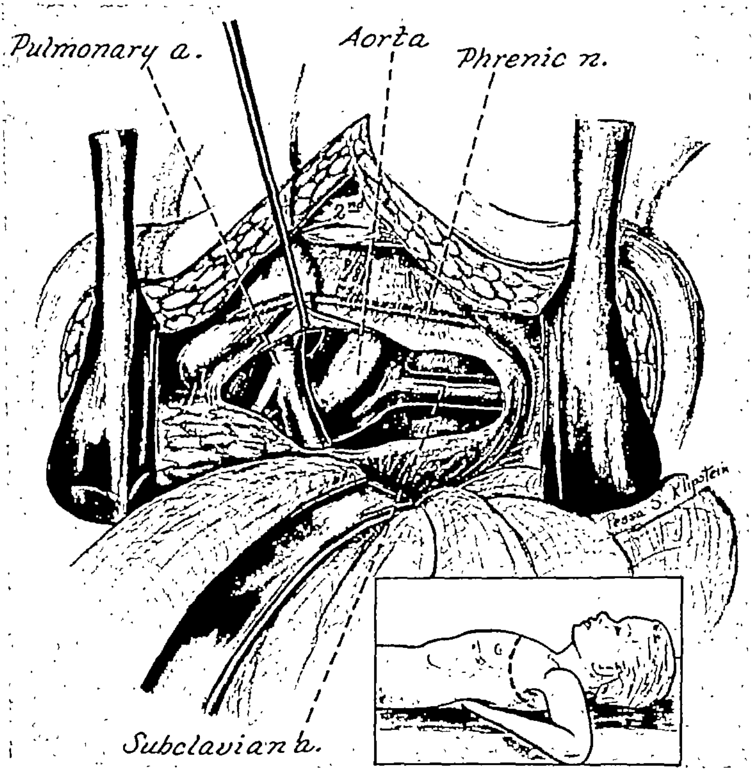

Fig. 4.—Operative field after preliminary dissection on the left side. The structures to be joined are evident with little or no dissection.

The one and only disadvantage to the left approach is the fact that a vessel which previously passed upward now passes almost directly downward, so that there is a tendency to kinking at the point of origin and through most or all of its new course it is in contact medially with a relatively unyielding structure, the convexity of the aortic arch. If the danger of compromising the free flow of

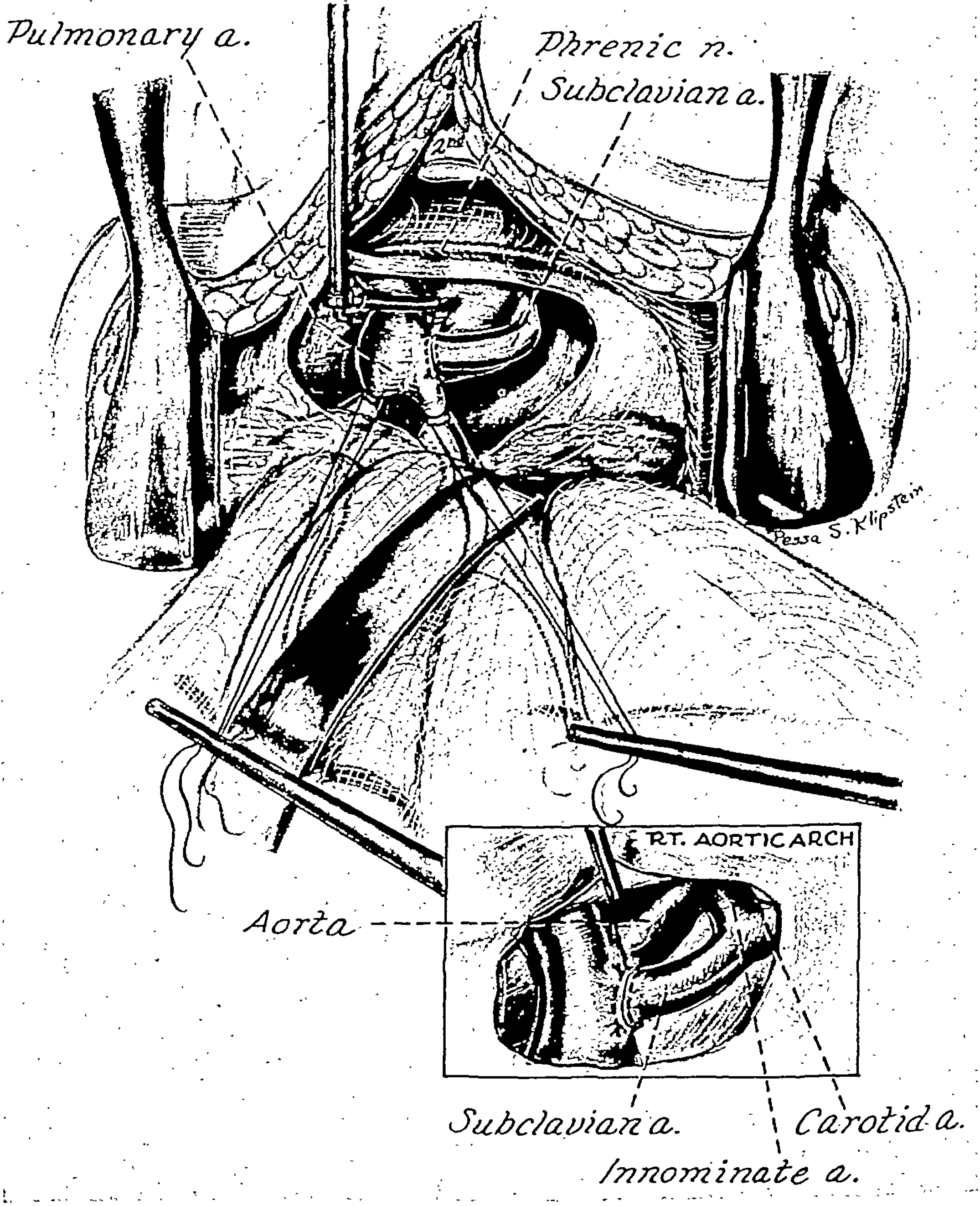

Fig. 5.—End-to-side anastomosis between the left subclavian artery and the pulmonary artery is complete. Inset: favorable angle of subclavian artery with innominate if there is a right arch.

blood through the shunt is considerable, this one disadvantage outweighs all of the advantages. There is some evidence that the danger is more theoretical than real. Holman used the left subclavian twenty-three times. In nineteen of these, he was satisfied with the blood flow following the anastomosis, and in the other four the pulmonary artery was divided proximal to the anastomosis to relieve the angulation, thus producing what was in effect an end-to-end anastomosis. All of these patients were markedly improved. Varco and his associates[6] utilized this vessel in nineteen operations and had eighten good results. Since we decided to use the left subclavian artery, fourteen of eighteen patients have had left arches. The operations were technically easy and all of the anastomoses functioned well immediately. At no time were we tempted to divide the pulmonary artery proximally. Unfortunately for the record, one patient who had a particularly large anastomosis with a good thrill, dramatic improvement in color, and a pleasing change in arterial saturation as recorded by the photoelectric oxyhemograph (Fig. 6), appeared to lose his shunt two days after operation. The loud ductus murmur disappeared. It is possible that a hematoma formed under the pleura which was sutured over the subclavian as it passed over the aorta. As a result of this experience, the pleura in this area will be left open in the future. Probably, the right subclavian will be utilized in a second operation.

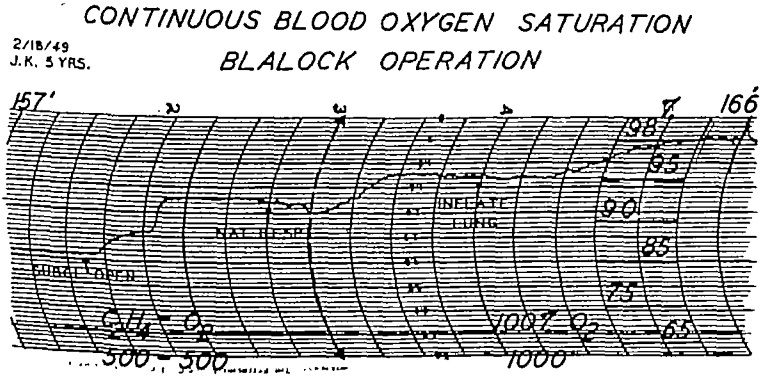

Fig. 6.—Nine minutes of record of photoelectric oxyhemograph showing immediate excellent function of a left subclavian-pulmonary anastomosis. (Record obtained by Dr. Vivien G. Behrman.) The shunt apparently closed two days later.

The only other patient in the series who failed to maintain his improved state following an apparently successful operation was a man of 24 years who died of cerebral embolism on the twelfth postoperative day. The arch was on the right.

The Potts procedure was planned for fifteen patients ranging in age from 5 months to 3 years. Seven babies were under 1 year of age and six of the others were under 2. The operation was technically successful in nine of ten patients with left arches and in two patients with complete dextrocardia. The right approach was used with complete satisfaction in the latter. However, difficulties were encountered when this approach was used in three patients with right arches and left hearts. In two, the Potts operation had to be abandoned because the aorta and pulmonary artery could not be approximated and unsatisfactory subclavian-pulmonary anastomoses were substituted. In the third, a poor aortic-pulmonary shunt was made with great effort, but the child expired. This was not the experience of Potts himself, who in 1947[7] reported that in twenty-nine patients, there were four with right arches and in each case he had been able to mobilize the pulmonary artery enough to bring the operation to a successful conclusion. The age of these four patients was not stated. In the age group of 3 to 7 years, no doubt the operation is quite feasible but it has been our policy to plan Blalock operations for this group. The ages of the three patients on whom we failed were 5 months, 7 months, and 10 months. It was our feeling that a Blalock operation on the right would have had an equal or better chance of success. The youngest of these children survived the technical failure and may live to have another operation on the left side. Our present position is that if a

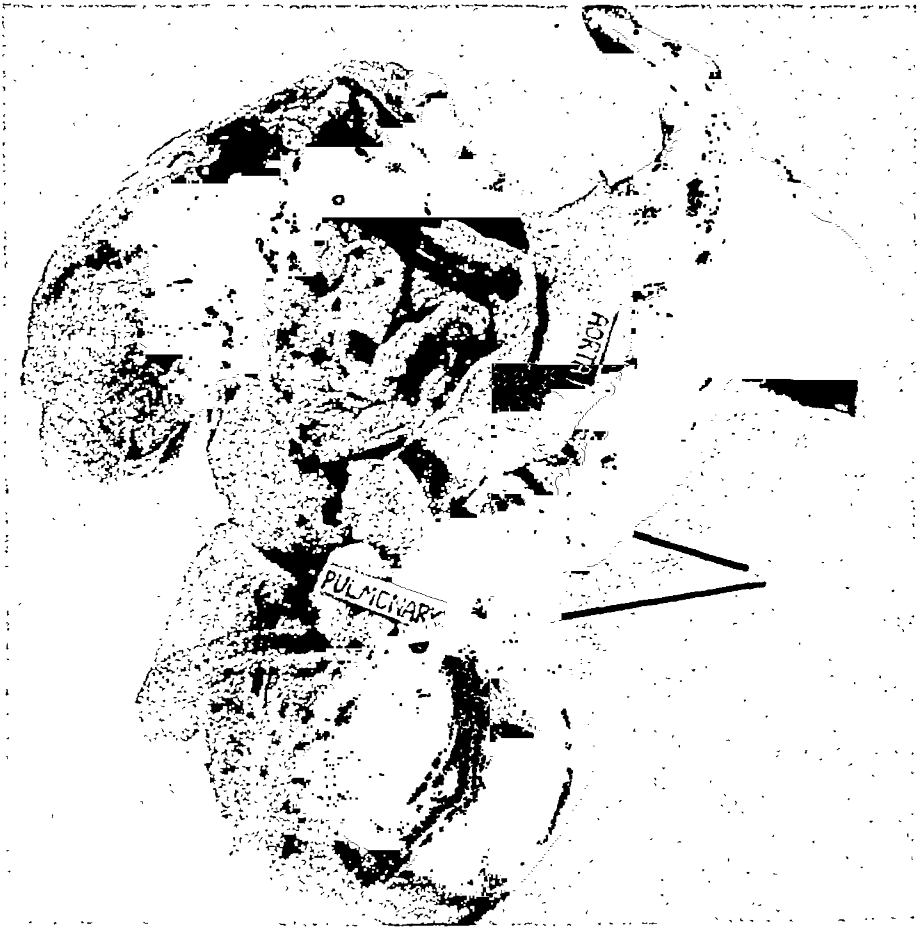

Fig. 7.—Autopsy specimen showing artificial ductus arteriosus (4 mm. in diameter) made by the Potts technique five months before. The ends of the transversely divided pulmonary artery are indicated by arrows, the lower of which points to the stenotic pulmonary valve.

child with a right arch and a left heart needs a shunt operation, we will plan a Blalock operation or nothing. This rule was applied to a moribund infant of four months with a right arch, on whom it was thought by the pediatric colleagues that operation might have some slight chance of success. Since he was too small for a Blalock operation and the right arch ruled out the Potts procedure for us, he was not accepted for any type of surgical procedure and expired a few days later. In this connection, it should be remembered that Blalock[2] suggests that if a child under 2 years has a 50 per cent chance of surviving, the operation should be postponed until that age is reached.

It is worth emphasizing again that if a Blalock operation has been planned and a suitable systemic vessel is not available, one has but to ask for the appropriate size of Potts-Smith clamp and proceed with a direct aortic-pulmonary anastomasis. Recently, a 4-year-old girl had a poor systemic vessel because the vertebral artery came off close to the aorta. An excellent aortic-pulmonary shunt was substituted for what would have been an inadequate operation.

There have been two late deaths in children who were improved in the immediate postoperative period following the Potts operation. A child operated on at the age of 6 months as a lifesaving measure lived 5 months and expired in cardiac failure. Autopsy showed a smooth, round artificial ductus arteriosus measuring 4 mm. in diameter (Fig. 7). The pulmonary stenosis was purely valvular. There was no ventricular septal defect, but a large interauricular opening. Children with this type of anomaly do poorly after any type of shunt operation, as compared with those with the more common tetralogy of Fallot. Valvulotomy would be the procedure of choice. Another child operated on at the age of one year was much improved until she died suddenly of an acute systemic infection thought to be meningococcemia. The autopsy showed no evidence of infection about the heart, and the smooth artificial ductus measured 2 by 3 mm.

Finally, a word should be said about the anterior versus the posterior approach for both operations. We have used the posterolateral approach through the fourth interspace without rib transection for children for whom the Potts procedure was planned. With one exception, we have employed the anterior approach through the second interspace for the Blalock operation, cutting the second costal cartilage. The exception deserves special mention. A wide posterolateral incision was made for a left subclavian-pulmonary anastomosis in a mentally defective child of 5 years. The internal mammary, vertebral, thyrocervical trunk and the continuing subclavian artery were ligated separately. Gangrene of the arm resulted and the child expired. Apparently if the subclavian artery is to be ligated in the above manner, it is unwise to cut the muscles of the shoulder girdle and their collateral arteries in order to make a posterolateral incision. In order to choose freely between the Blalock or Potts procedures after the chest is opened, one should enter the chest anteriorly.

SUMMARY

Fifty operations for pulmonary stenosis or atresia have been carried out at the Henry Ford Hospital following diagnostic procedures by Dr. Robert Ziegler and Dr. Mason Sones. There were thirty-one Blalock operations, and fifteen Potts operations; four times no shunt was completed. Anatomic factors which make the surgical procedures difficult or easy and which influence the end results have been discussed. Technical difficulties during each operation when the right approach was used have caused us to adopt the following simple rule for choosing the side for operative approach: the incision is made on the side of the apex of the heart, regardless of the position of the aortic arch or the age of the patient.

REFERENCES

1. Blalock, Alfred, and Taussig, Helen B.: The Surgical Treatment of Malformations of the Heart in Which There Is Pulmonary Stenosis or Pulmonary Atresia, J. A. M. A. 128: 189, 1945.
2. Blalock, Alfred: Surgical Procedures Employed and Anatomical Variations Encountered in the Treatment of Congenital Pulmonic Stenosis, Surg., Gynec. & Obst. 87: 385, 1948.
3. Potts, W. J., Smith, Sidney, and Gibson, Stanley: Anastomosis of the Aorta to a Pulmonary Artery, J. A. M. A. 132: 627, 1946.
4. Jenkins, H. P., Senz, Edward, Owen, Howard, and Jampolis, Robert: Control of Arterial Hemorrhage by a Gelatin Sponge "Cuff" and Chromic Surgical Gut Sheath, Arch. Surg. 55: 637, 1947.
5. Holman, Emile: Experiences With the Anastomosis of the Left Subclavian Artery to the Left Pulmonary Artery for Pulmonary Stenosis, Read at the Twenty-eighth Annual Meeting of the American Association for Thoracic Surgery, Quebec, June 2, 1948.
6. Varco, R. L., Merendino, K. A., and Miller, F. A.: Surgical Treatment of Pulmonic Stenosis, Bull. Univ. Minn. Hosp. & Minn. Med. Found. 20: 117, 1948.
7. Potts, W. J.: Aortic Pulmonary Anastomosis for Pulmonary Stenosis, J. THORACIC SURG. 17: 223, 1948.

DISCUSSION ON "A METHOD FOR EXPOSURE OF THE CARDIAC SEPTA" BY DR. F. D. DODRILL,* AND "THE CHOICE OF THE SITE FOR APPROACH IN OPERATIONS FOR PULMONARY STENOSIS" BY DR. CONRAD R. LAM

DR. JOHN C. JONES, Los Angeles.—I would like to emphasize one point, and that is that if, in the case of a small infant, there is doubt about on which side the aorta descends, the approach is best made on the left side. I cite one case to emphasize the fact that the surgeon should not be entirely baffled if he does find that he is on the side on which the aorta is not present even if before the operation he had intended to carry out the Pott's operation. We operated on an infant about three months ago who was 8 weeks old at the time. The child had become cyanotic suddenly at the age of 6 weeks and was brought to the hospital about ten days later, was in oxygen continuously and, of course, was deteriorating rapidly and the clinical study was quite inadequate. In fact we were not certain whether the aorta descended on the right or on the left; the clinical diagnosis was the tetralogy of Fallot. We approached the operation from the left and found the aorta was on the right side. It would have been fatal, of course, to have allowed the child to continue in this way, because without an anastomosis it was unlikely that she would have survived. It was an emergency and the child was in poor condition. By dissecting the carotid and the subclavian arteries, carrying the carotid dissection well up into the neck, we were able to bring the subclavian artery down on the left side and anastomose it to the pulmonary artery. Even though it appeared to be a small subclavian artery, anastomosis was technically feasible; there was an excellent thrill in the pulmonary artery and the child made an uneventful convalescence and went home ten days after operation in excellent condition.

It is three months since operation and while it may be that she will return later on and may need another shunting operation, the point is, I think, that if one is in doubt whether the aorta lies on the left or on the right, one should go in on the left even if the aorta is on the right, rather than chance having a bad angle on the right side with the Potts operation, and to proceed with the Blalock operation by a good dissection going well up into the neck and using the subclavian artery to anastomose to the pulmonary artery. This case convinced me that the Blalock operation is feasible in tiny infants.

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*See page 652 for article by Dodrill.

DR. W. J. POTTS, Chicago.—We have come to somewhat similar conclusions for slightly different reasons. I wish to discuss briefly our procedure with right arches in cases of pulmonary stenosis. (Slides.)

In the first twenty-two patients we did aortic pulmonary anastomoses on the right, in patients from 4 months to 17 years of age. In that group we have had two deaths, one from anoxia and another from prompt and complete closure of the anastomosis. We have done subclavian pulmonary anastomosis more recently on eleven patients with right arches with no deaths and satisfactory results. We have made five explorations with two deaths; none of these patients had a pulmonary artery. There were no patients in this group in whom we failed to make an anastomosis if there was a pulmonary artery. One two-year-old child had closure of the anastomotic channel. A satisfactory subclavian pulmonary anastomosis was later done. A total of 37 of 175 patients operated upon for pulmonary stenosis had right aortic arches (21 per cent).

There have been a few interesting variations from the usual procedure. In this case closure of the pulmonary artery in preparation for anastomosis on the right side led to prompt signs of impending death. The pulse dropped and the blood pressure fell. A branch to the upper lobe of the lung was tied off distally and the proximal end was anastomosed to the side of the aorta. The boy made a satisfactory recovery. There have been no signs of change in the lung. This case was previously reported by Dr. Sidney Smith.

A similar situation presented itself in a second patient with a right arch. Closure of the *pulmonary* artery in this case also led to a severe drop in blood pressure. We used a new type of clamp which occluded a tangential portion of the pulmonary artery and left enough room to do the anastomosis while a fair amount of blood went to the left lung. As you see, we did an over-and-over suture. We did not do an intima-to-intima anastomosis. Recovery was satisfactory.

This is our present policy: If the arch curves to the right we do a subclavian pulmonary anastomosis. If the patient is an infant in whom presumably the subclavian will be too small, the right side is entered and an aortic pulmonary anastomosis done. In all patients with a left aortic arch we routinely do an aortic-pulmonary anastomosis.

DR. SANFORD E. LEEDS, San Francisco.—Since Dr. Lam mentioned the use of the branch of the right pulmonary artery to the right upper lobe, I would like to elaborate on that point. We have employed the right-sided approach in younger patients who have a left aortic arch. (Slides.)

We have had difficulty in some of our cases due to a short right subclavian, short pulmonary artery, or high take-off of the right subclavian from the innominate artery.

It was thought that it might be possible, where there are short vessels, to use the *branch* of the pulmonary artery to the right upper lobe, doing an end-to-end anastomosis between the proximal end of the branch and the right subclavian artery.

This procedure was first tested in dogs by anastomosing the left subclavian artery to the proximal divided end of the left pulmonary artery. The experiments showed that the entire left lung could survive with the pulmonary artery divided and also the heart showed no enlargement or other abnormality from the shunt after observation for several months.

The procedure has now been used with excellent results in four cases of tetralogy of Fallot. It seems advantageous to sacrifice the pulmonary circulation to a portion of the lung in selected cases rather than to use the innominate or carotid artery and run a greatly increased risk of cerebral complications.

An additional purpose for this procedure is when there is an absence of the left pulmonary artery or if there has been a thrombosis of the left pulmonary artery from a previous operation. In these cases the branch of the right upper lobe may be occluded at its origin from the right pulmonary artery by means of a bulldog clamp and the anastomosis may then be carried out without occluding the main right pulmonary artery.

DR. LAM.—There was nothing said in the discussion with which I can disagree, but I cannot miss this opportunity to have the last word in this symposium. I hope that I was able to convey the idea that one of the advantages of the left approach is that one can use Dr. Potts's very clever operation in case one is unable to use the subclavian artery.

PULMONARY RESECTION FOR COCCIDIOIDOMYCOSIS

REPORT OF A CASE

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PULMONARY coccidioidomycosis, with residual cavity or nodule formation, occurred frequently among military personnel stationed in endemic areas in the southwest during World War II.[1, 2] Relatively few reports of surgical resection for these lesions have appeared in the literature.[1-4] In many instances, nodular lesions were resected as tumors of undetermined origin.[1] It is proposed here to report a case of cavitary coccidioidomycosis diagnosed prior to surgery and brought to resection because of prolonged hemoptysis and progression of the disease.

CASE REPORT

A 26-year old, white man was admitted to this hospital Dec. 29, 1947. The patient's chief complaint on admission was pain in the right chest, weakness, increasing fatigue, and hemoptysis. The patient dated his illness to June, 1942, at which time he had first noted weakness and right chest pain. In August, 1943, after a year of service in Arizona, a roentgenogram of the chest was taken due to an episode of chills, fever, and right chest pain. A diagnosis was made of pneumonitis, probably due to coccidioidomycosis, and the patient was hospitalized. He remained in service hospitals, presumably because of persistent pulmonary disease, until the time of his discharge from the army in January, 1945. Immediately after his discharge from the service, the patient entered the Veterans Administration Hospital at Dearborn, Mich., where he remained for two weeks until he was discharged. Chest x-ray picture at this time revealed a thin-walled cavity in the right upper lobe. He returned to his former occupation as a molder in a foundry for six months following his discharge from the hospital, but he was unable to carry on his duties in this capacity due to the recurrence of a severe cough with expectoration of a profuse amount of mucopurulent sputum. These symptoms persisted for the next two years. In addition to the cough the patient had experienced recurring episodes of weakness and at times pain in the right anterior chest wall not definitely related to the respiratory movements. In July of 1946, the patient entered Sunshine Sanitarium in Grand Rapids, Mich., for two weeks. At this time examination of the sputum and gastric contents revealed no evidence of tubercle bacilli, and roentgenograms revealed that the cavity had increased in size. Clinical course was unchanged until nine days prior to admission to this hospital when the patient noted an increase in cough with expectoration of blood-streaked sputum, increasing weakness, and night sweats. The patient's expectoration of blood increased until the time of admission, at which time he was having moderately severe hemoptysis daily. This continued during his stay in the hospital and up to the time of his operation.

A review of the family history revealed that the patient's father had died at the age of 52 of pulmonary tuberculosis and one brother among sixteen children had also died of pulmonary tuberculosis.

The patient's occupational history was significant in that he had worked in a foundry as a molder for two years prior to his service with the Armed Forces and had worked at this occupation for six months in 1945.

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Physical examination on admission revealed a well-developed, moderately well-nourished, white man who did not appear acutely ill. The mucous membranes of the nose and pharynx were injected and edematous. The remainder of the head and neck examination was negative. Examination of the chest revealed decreased tactile fremitus in the right scapular area. The percussion note was resonant throughout. The breath sounds over the right base were bronchovesicular in character and fine posttussive râles were heard over the right posterior chest. The blood pressure was 128 systolic over 70 diastolic and the pulse was 88 beats per minute. The heart was normal in size and position and no murumrs were heard. The abdomen was negative to palpation and auscultation. A yellowish white mucous discharge from the penis was noted. The remainder of the physical examination was essentially negative.

A roentgenogram taken at this institution on Jan. 2, 1948, revealed a large, irregular ring lesion in the right upper lung field, 3½ × 7 cm., which was compatible with a thin-walled cavity (Fig. 1). No other pathologic changes were noted. Sinus roentgenograms taken on January 13 revealed no involvement of the paranasal sinuses. Bronchograms performed on Feb. 3, 1948 showed the previously described cavity in the right upper lobe of the lung with surrounding fibrotic changes. No lipiodol was seen in the cavity and no bronchiectasis or other abnormality could be demonstrated.

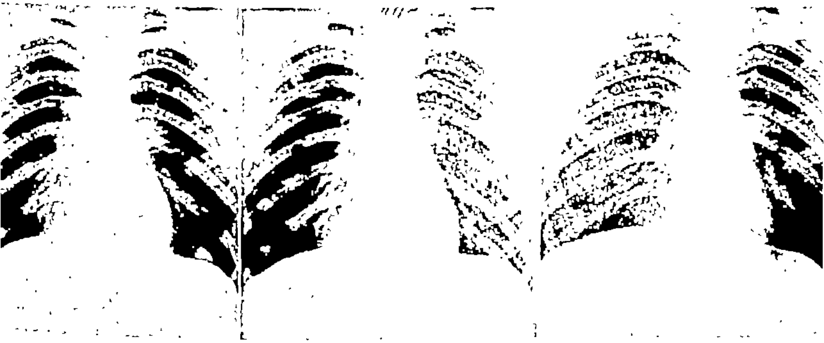

Fig. 1.—Roentgenograms (reading from left to right) taken in 1946, 1946, and 1948, respectively, showing progression of cavitary lesion in right upper lobe.

Clinical examination on admission revealed a white blood count of 16,000; hemoglobin was 12 Gm. per 100 c.c. of blood; the urine was completely negative. Serologic tests for syphilis were negative. A coccidioidin skin test 1:100 was positive. A second strength purified protein derivative was positive. The blood count on January 5 showed white blood cells to 10,800 and hemoglobin was 13.5 Gm. per 100 c.c.; the sedimentation rate was 15 mm. in one hour. Three gastric aspirations, twelve concentrated sputum smears, and ten sputum cultures for acid-fast bacilli were negative. The gram stain of the urethral discharge revealed gram-negative intracellular diplococci. The patient had repeated examinations of the sputum by smear and culture for coccidioides immitis. These were all negative up to the end of January when sputum cultures were found to be positive. His clinical tests on January 20 showed white blood cells to number 11,500 and the hemoglobin was 15 Gm. per 100 c.c. of blood. The prothrombin time on Jan. 20, 1948, was twelve seconds or 100 per cent, and the bleeding time was one minute, and the coagulation time was three minutes.

The patient was treated with intramuscular penicillin following his admission for a period of three days with no clinical change in his condition. He continued to cough and expectorate large quantities of sputum and blood; the quantity varied from one-half pint to approximately one pint daily. The temperature was usually normal with occasional periods in which it would suddenly rise to 102° F. and return to normal within twenty-four to forty-eight hours.

On Jan. 17, 1948, a bronchoscopic examination was performed which revealed a marked purulent discharge from the right upper lobe bronchus, but no other abnormality of the endobronchial tree was noted.

The steady increase in size of the cavity over the three-year period of x-ray observation, the disabling character of the symptoms of weakness, cough, and copious purulent sputum, and the persistent hemoptysis led to the decision to resect the diseased right upper lobe.

On Feb. 10, 1948 a right thoracotomy was performed following preliminary bronchoscopy. At the time of preliminary bronchoscopy, a pack was placed in the right upper lobe bronchus but due to a rather marked vagovagal reflex and bronchospasm, the pack was removed and the patient was then intubated and he was operated on in the face-down, Trendelenburg position under oxygen pentothal curare anesthesia. A primary incision was made in a curved manner in the right paravertebral space swinging down below the inferior angle of the right scapula. The scapula was retracted and a posterolateral portion of the fourth right rib was removed subperiosteally. The pleural cavity was entered. There were dense adhesions between the upper lobe and the parietal pleura. In these areas, to avoid soiling of the pleura, careful dissection in the endothoracic fascial plane was carried out, leaving the parietal pleura attached to the lung, and the entire right lung was freed from the chest wall. The cavity in the upper lobe was easily felt on palpating the lung and in addition small hard nodules could be felt scattered throughout the upper lobe; this nodulation was also felt in the apex of the lower lobe. The visceral pleura appeared to be thickened and moderately opaque over the entire right lung.

The bronchus was then isolated in the posterior portion of the hilum. There were numerous glands in the mediastinum and these were removed along with the lung tissue. The bronchus was then clamped and cut through proximal to the clamp. The bronchus was closed with a single row of interrupted black silk sutures. The pulmonary artery to the upper lobe was then isolated, ligated, and divided. The superior pulmonary vein was isolated, ligated, and sectioned. There were no distinct fissures between the right upper lobe and the lower lobe nor between the right upper and the middle lobe except at the periphery of the lobes. Therefore, these fissures were developed with excision of portions of the lower and middle lobes to avoid spillage from the upper lobe. The fissures thus created were partially closed with interrupted white cotton sutures which were placed superficially to gain hemostasis and to close any obvious bronchial leaks on the lung surface. The bronchial stump was covered with a mediastinal pleural flap and the entire hilum of the lung at the resected level of the upper lobe was closed by a covering of the mediastinal pleura. The remaining right lung was re-expanded under positive pressure and the chest cavity was closed with moderate suction on the intrapleural space during closure. A drainage tube was placed in the posterior axillary line in the sixth interspace and was attached to a subaqueous drainage bottle. The chest wound was closed in layers using interrupted cotton sutures for the chest wall and black silk sutures for the skin. Penicillin 200,000 units in 5 c.c. of saline were left in the pleural space. The patient's postoperative condition was satisfactory.

PATHOLOGIC SPECIMEN

Gross Description.—The specimen consisted of a right upper lobe of the lung. The pleura was dull and covered with fibrinous shreds. In the upper one-third, there was a bulge to the surface. On section into this area, a cavity was found, which after fixation, measured 3.5 × 2.0 cm. (Fig. 2). The wall of the cavity consisted of a layer of white, fibrous tissue, averaging 5 mm. in thickness. The inner surface was granular and somewhat velvety appearing and was grayish brown in color. Within the cavity and coating the wall, there were many crumbly, yellow patches resembling sulphur particles. Smears and cultures were made of these particles and from the wall of the cavity. The surrounding lung tissue appeared to be moderately indurated. There were many small nodules, each measuring approximately 3 to 5 mm., which surrounded the cavity particularly at the lower portion. The entire lung had a slightly increased consistency, this being more marked in the vicinity of the cavity.

Microscopic Description.—The cavity was lined by a thin layer of necrotic cells and polymorphonuclear leucocytes. There were areas, however, in which no lining was apparent. Both within the cavity wall and deep in the tissue there were foci of epithelioid cells. Some of these cells were also multinucleated giant cells resembling Langhans' giant cells. There was considerable destruction of lung tissue and replacement by fibrous tissue and foci of lymph follicles. The bronchi were often filled with polymorphonuclear cells. In none of the sections examined were spherules found.

Direct smears of the granules lining the cavity revealed mycelia and hyphae consistent with those obtained from cultures of *Coccidioides immitis.*

Cultures of this material yielded characteristic colonies of *Coccidioides immitis.* These were inspected and confirmed by Dr. C. W. Emmons, National Institute of Health, and Dr. N. F. Conant of Duke University.

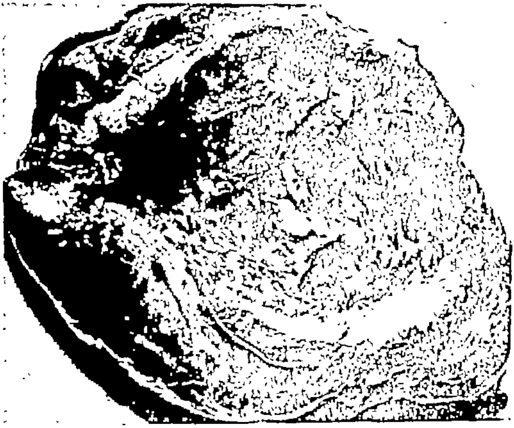

Fig. 2.—Gross specimen demonstrating cavity in cut section of right upper lobe.

Inoculation of culture material into guinea pigs resulted in a granulomatous lesion containing typical spherules of *Coccidioides immitis.*

The patient's postoperative course was uneventful and he was ambulatory on the day of surgery. On the second postoperative day the temperature rose to 100° F. and returned to normal where it stayed during his convalescence. There was a drainage of approximately 600 c.c. of serosanguineous, clear fluid from the chest in the first two postoperative days, after which time the tube stopped draining and fluctuating despite irrigation. The drainage tube was removed on the third postoperative day and no further aspirations were required.

The clinical examinations during the postoperative period were not significant except for a fall in the serum protein. On Feb. 11, 1948, the first postoperative day, the serum protein was normal at 6.4 Gm. per 100 c.c., consisting of 3.6 Gm. of albumin and 2.8 Gm. of globulin. The serum protein fell on Feb. 14, 1948, to 5.8 Gm. per 100 c.c. (3.8 Gm. of albumin and 2.0 Gm. of globulin), and remained at this level for the next three weeks when it gradually returned to normal.

The patient was well enough to return to his home on the ninth postoperative day. He returned to the hospital for postoperative re-evaluation on the first of March, 1948. He has had no complaints referable to the chest and no further expectoration of sputum or blood.

The postoperative roentgenograms of the chest showed an immediate satisfactory aeration of the residual portion of the right lung. On Feb. 11, 1948, the x-ray picture revealed satisfactory aeration of the residual lobes of the right lung with an estimated 20 per cent pneumothorax remaining in the upper portion of the chest. The remaining lung was very slow to fill the upper portion of the chest and at the time of his discharge from the hospital, this was not completely filled. However, there was no evidence of fluid nor of any increased reaction in the pleural space. The last roentgenogram of the chest taken on March 10, 1948, revealed the changes in the right chest incidental to the right upper lobectomy with partial resection of the fourth right rib. The residual right lung had expanded to a level with the second right rib posteriorly with a space between the lung and the upper chest wall. There was also some residual lipiodol in both lower lung fields. Otherwise the chest examination was negative.

A postoperative coccidioidin skin test was negative in twenty-four and forty-eight hours. Three gastric cultures for acid-fast bacilli, which were taken following the patient's operation, were also reported as negative. The other clinical studies on this patient, including the blood and the urine were all within normal limits. The patient was, accordingly, discharged from the hospital to return to his home on March 15, 1948.

COMMENT

Of interest in this patient was the persistence and progression of the cavity five years after the onset of the disease. In addition, the apparent presence of cultures of the fungus growing on the wall of the cavity, with mycelia and hyphae present, is most unusual. In the commonly present spherule form, the disease is said to be noncontagious. However, the finding of mycelial forms in this patient, as in the one preceding case in which this finding was recorded,[5] raises the question of the infectiousness of the disease in patients with long standing, progressive cavities due to coccidioidomycosis, and further justifies surgical extirpation of the disease.

REFERENCES

1. Forbus, W. D., and Bestebreurtje, A. M.: Coccidioidomycosis, Mil. Surgeon 99: 653-719, 1946.
2. Smith, C. E.: Recent Progress in Pulmonary Mycotic Infections, California Med. 67: 179, 1947.
3. Churchill, E. D.: Malignant Lymphoma of the Lung and Pulmonary Coccidioidomycosis, S. Clin. North America, p. 1113, 1947.
4. DeLamater, E. D., and Weed, L. A.: Budding in Tissue Phase of Life Cycle of Coccidioides Immitis; Preliminary Report, Proc. Staff Meet., Mayo Clin. 21: 505-509, 1946.
5. Barnes, H. R.: (Discussion) Pulmonary Coccidioidomycosis, Dis. of Chest 12: 383-385, 1946.

CARCINOMA OF THE LUNG

A Follow-Up on Sixty-Seven Patients Subjected to Pneumonectomy

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SINCE 1936, we have seen, in association with the Jackson Clinic, 429 patients who have been proved to have carcinoma of the lung. We have purposely limited this study to those cases preceding November, 1947, so that a six months' follow-up could be obtained on even the last case analyzed. Patients who have been seen since that time have not been included.

Of this group of 429 cases, 149, or 34.7 per cent, were considered as possibly operable. Of the 149 patients explored, 67, or 15.6 per cent, of the total were subjected to pneumonectomy, which was routinely performed if there was any hope of cure. The general condition or the age of the patient influenced us only slightly in choosing these patients for operation. Therefore, in certain cases, marked risks were taken in an effort to salvage a possible cure.

It is not the purpose of this paper to consider diagnosis or details of operability, but it seems important at least to state that several patients operated upon did not show x-ray findings suggesting tumor, but the diagnoses were made by other methods, especially bronchoscopy, and exploration was considered worth while if there was no definite evidence of widespread metastasis. In this report we are concerning ourselves chiefly with the 67 pneumonectomized patients, since we believe that the most important consideration is the final salvage.

We have been impressed by the difficulty of making a gross diagnosis at the operating table and have attempted to make a positive diagnosis preceding operation whenever possible. Diagnostic measures have included bronchoscopy, needle biopsy, and, recently, cytologic study of bronchial secretions. Over 90 per cent of our patients have been taken to the operating room with a positive diagnosis. We do not believe much time should be wasted in making this diagnosis, and we rarely study a patient more than two weeks before surgery.

Of the 67 patients submitted to pneumonectomy, certain interesting statistical data have been gathered. The oldest patient in this group was 66 years of age and the youngest 36; the average age was 54 years. We have seen patients much older and much younger than these, but none in our group has been operable. One 27-year-old patient was treated by lobectomy a couple of years before we performed our first pneumonectomy in 1938. He rapidly developed a local recurrence, which we suspect was present in the lymph nodes at the time of the original lobectomy. We have generally avoided lobectomy as a treatment for carcinoma of the lung, although the relatively low mortality figures of lobectomy are certainly intriguing and have not been matched by any series of pneumonectomies.

Of the 67 pneumonectomized patients, 18 or 27 per cent, died in the hospital. Nine died of cardiac complications; the average time was 5.5 days after operation. Two died on the operating table. One died of a proved pulmonary

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embolus within twenty-four hours of operation. One died of what was suspected of being a procaine reaction three days after operation.

Five died of infection. Since 1942, however, when we first started using penicillin, we have lost only one patient from infection, and almost invariably our mortality is due to cardiac complications. Of the remaining 49 patients, 27, or 40.2 per cent of the 67, have died since leaving the hospital. Twenty-two died of metastasis or from extension of the primary lesion in an average time of 11.4 months. Two have died of subsequent carcinoma elsewhere which apparently had no relation to the pulmonary growth. One died of carcinoma of the stomach five months after the pneumonectomy; the second died of adrenal carcinoma twenty-four months after pneumonectomy. In both of these cases we must at least suspect that the tumor of the lung was secondary to the other tumors from which the patients died, but we have no definite proof of this and in each instance the type of tumor was different. Three died of other causes: one of coronary thrombosis ninety-five months after operation; one of diabetic coma twelve months after pneumonectomy; and one of undetermined cause forty-one months after pneumonectomy.

The next group we consider to be the most important. Still living are 22 patients, or 32.8 per cent of the original 67. Twenty are known to be perfectly well, and although this is 30 per cent of our pneumonectomized patients, it is only 4.7 per cent of the 429 originally seen. Of the two patients who are known to be not entirely well at the present time, one is suspected of having metastatis eleven months after pneumonectomy, although this has not been proved. One is still living, forty-nine months after pneumonectomy, although she has a carcinoma of the ovary which has metastasized retroperitoneally. She is now being treated for this carcinoma of the ovary, which is thought to have no relation to the carcinoma of the lung. Of the 20 patients who are known to be living and well, 16 are working regularly.

Of the 22 surviving patients, 11 have been followed from six months to two years and 11 have been followed for periods of over two years. Our oldest living patient has been followed for ninety-seven months and is perfectly well. He has undergone two subsequent operations for other complaints since his original pneumonectomy, and has stood them well. Of the 15 patients who have survived for as long as two years, 11 are still living. Of the 49 patients who survived hospital stay, 15 had gross mediastinal lymph node metastasis. Thirty-four, therefore, had no gross or microscopic mediastinal lymph node metastasis; 26 per cent of those with lymph node metastasis are still living and 53 per cent of those without lymph node metastasis are living.

Another interesting statistical feature concerning the number of patients who have survived over three years, 8 in number in our series, is that half had lymph node metastasis and half did not. So it seems that if lymph node metastasis is present, the patient will either die in a relatively short period of time or will have as much chance to survive as one without lymph node metastasis.

Preoperative preparation is worthy of mention, although we do not intend to discuss it here in detail. It should include a thorough examination of the patient to exclude distant metastasis, which would contraindicate operation, and to evaluate any complication which might influence morbidity and mortality.

X-ray examination of the chest is, of course, essential. This must include fluoroscopic examination of the diaphragm because we have found that, in the presence of tumor, phrenic-nerve paralysis indicates mediastinal invasion.

In the past few years, we have eliminated routine skeletal survey for metastasis because it has seemed to us that skeletal metastases from carcinoma of the lung are almost invariably painful and thereby make their presence suspected. Thus skeletal survey seems indicated only in those patients with so-called bone pain.

Cardiac survey, including electrocardiogram, is essential. We have recently been including circulation time and an overload test which so far have seemed to be a helpful indication of cardiac reserve. The overload test is done by introducing 10 c.c. of saline per pound of body weight into the patient's venous circulation in thirty minutes. Venous pressures and circulation time are taken before and after introduction of the fluid. If the patient develops any untoward symptoms, such as shortness of breath or cyanosis, during the introduction of the fluid, it is immediately stopped.

Bronchoscopy is routinely utilized in an attempt to obtain adequate biopsy and also to determine the exact location of the lesion. Bacteriology of the sputum and bronchial secretions is routinely checked. We have noted that tuberculosis and carcinoma occasionally appear together. Also, routine cultures and susceptibility tests have aided us in choosing antibiotic therapy, which is employed routinely. We consider 200,000 units of penicillin daily for five to seven days before operation, in divided doses, as usually adequate. We have utilized streptomycin when bacteriologic determination indicates it. Recently, we have routinely been employing aerosol inhalations three days before surgery. Repeat bronchoscopy is employed when secretions are excessive or when there is definite bronchial block which might be benefited by bronchoscopy. We have routinely inserted 100,000 units of penicillin and 1 Gm. of streptomycin into the thorax at the time of operation. We have generally utilized approximately 3 Gm. of sulfanilamide powder in the pleural space, but this has recently been discontinued.

Postoperative care has been directed mainly toward symptomatic treatment. In general, we have utilized oxygen for at least twenty-four hours and often longer. We have introduced penicillin and streptomycin into the thorax whenever aspiration for pressure readings was necessary. We have employed low-fluid intake for the first week after operation. We believe that ambulation in patients who have had pneumonectomy should not be hurried. Mild exercise in bed and frequent change in position are encouraged. Undue effort might well throw these patients into cardiac failure, should failure be impending. When patients are permitted out of bed following pneumonectomy, we keep motion as passive as possible.

The drug that has been most helpful to us in treating cardiac failure or impending failure has been digitalis. We have been fearful of using it routinely, but have employed it in adequate dosage when the patient's pulse becomes unduly rapid or when any symptoms suggesting failure appear. If any measures have aided our treatment of impending failure, they have been limitation of fluids and the judicious use of digitalis.

Operative technique has not varied tremendously in the past few years. We generally make our approach through the third interspace anteriorly, since anesthesia is more easily maintained and the mediastinum seems quite accessible from this approach. We routinely ligate the pulmonary artery before the veins are ligated. We generally dissect out the individual vessels before ligating any of them, so that we may perform our operation in stages if the patient's condition seems to warrant it. All vessels are transfixed as well as ligated. At present, we have no definite opinion about bronchial closure. We know of no superior method. If possible, we prefer to pleuralize the bronchial stump.

During the past two years, we have routinely left a small catheter in the thorax for several days, so that changes in pressure can be readily remedied and antibiotics introduced daily. We have done thoracoplasty later only on those patients who developed empyema following surgery. Thoracoplasty then is utilized after the patient has entirely recovered from the pneumonectomy and subsequent postoperative infection, usually in about six weeks to two months. We have not found that these few patients had more pulmonary reserve or better cardiac function than those in whom thoracoplasty was not used.

The extent of our operative procedure has, incidentally, been somewhat variable. We have not hesitated to take out a portion of chest wall when it seemed necessary because of the extent of the tumor; one patient who is living and well thirty-one months after pneumonectomy had a portion of five ribs resected. We have taken out portions of pericardium and, on one occasion, went slightly across the carina in an attempt to remove all obvious tumor. We do not consider any risk too great to take if there is a chance of cure.

COMMENT

It is very difficult to evaluate statistics which have been obtained on such a variable group of cases. It seems very discouraging when one realizes that the salvage rate on 429 patients originally seen is only about 4.7 per cent. It is also somewhat discouraging when we realize that only 149 of these original patients were even subjected to surgery. Of the group who were not operated upon, many patients had very obvious contraindications to surgery when first seen. We have not and do not intend to censor physicians for sending us obviously inoperable cases for evaluation; these patients have been given at least the benefit of careful evaluation, and occasionally palliation has been afforded them by x-ray therapy. We are much more interested in stressing early diagnosis, which will be the most important factor in improving our salvage rate. It is at least hopeful that we have been able to salvage the occasional case.

Certainly the figures that have been accumulated compare favorably with the treatment of carcinoma of the stomach. It is also difficult to evaluate mortality. Our mortality from infection has been largely eliminated, and since 1942 the over-all figures have been reduced chiefly by the use of antibiotics. Our present mortality rate is approximately 20 per cent. Mortality apparently must still depend on the condition of the patient who is being operated on. This mortality is largely due to cardiac failure. We must, therefore, improve our methods of handling this complication. During one period we had fifteen consecutive pneumonectomies without any infection and without mortality.

We have not been able to find any particular reason for this unusual run of what we must consider good luck, and I believe that we will have to attribute it to the fact that we were operating on patients who were better risks than usual.

If we cannot reduce the mortality of pneumonectomy, we must consider lobectomy in some patients who have peripheral lesions. Pneumonectomy is certainly ideal since it affords adequate hilar dissection, but the figures of Neuhof are intriguing, and in our own cases we found only eighteen out of sixty-seven who had hilar lymph node involvement, and this lymph node involvement could have been almost universally predicted because of the location of the lesion. In the light of these reports, it would seem that we must either lower the mortality of pneumonectomy or strongly consider lobectomy in certain peripherally located lesions. The ideal operation is assuredly pneumonectomy.

SUMMARY

Sixty-seven pneumonectomies which have been followed for a period of from six to ninety-nine months have been discussed. The salvage is definite though small, 32.8 per cent. Careful evaluation of the patient preceding surgery is very important. Early diagnosis should considerably improve the operability rate. The most important condition producing postoperative mortality is cardiac failure, infection having been largely eliminated by antibiotic therapy and careful technique. The operative mortality of pneumonectomy must be reduced or lobectomy must seriously be considered in certain peripheral lesions. Twenty patients are living and well for six months to ninety-nine months following pneumonectomy and two others have died of unrelated causes.

REFERENCES

1. Adams, Ralph: Carcinoma of the Lung, J. Thoracic Surg. 17: 306, 1948.
2. Alexander, J., and Haight, C.: Pulmonary Resection for Solitary Metastatic Sarcomas and Carcinomas, Surg., Gynec. & Obst. 85: 129-140, 1947.
3. Bailey, Charles P., Tropea, Frank, Jr., and Rubenstein, L. H.: Recent Advances in Pulmonary Surgery, S. Clin. North America 27: 1373-1405, 1947.
4. Birath, G., Crafoord, C., and Rudström, P.: Pulmonary Function After Pneumonectomy and Lobectomy, J. Thoracic Surg. 16: 492-511, 1947.
5. Coleman, F. P.: Primary Carcinoma of the Lung With Invasion of the Ribs. Pneumonectomy and Simultaneous Block Resection of the Chest Wall, Ann. Surg. 126: 156-168, 1947.
6. Effler, Donald B., and Blades, Brian: Surgical Treatment of the Solitary Metastasis, J. Thoracic Surg. 17: 27-37, 1948.
7. Gibbon, J. H., Jr., Clerf, L. H., Herbut, P. A., and DeTuerk, J. J.: The Diagnosis and Operability of Bronchiogenic Carcinoma, J. Thoracic Surg. 17: 419, 1948.
8. Jones, J. C.: Surgical Aspects of Bronchogenic Carcinoma, J. A. M. A. 134: 113-117, 1947.
9. Neuhof, Harold, Rabin, C. B., and Sarot, I. A.: A Topographic Classification of Cancer of Lung With Special Reference to the Surgical Implication of the Circumscribed Variety, J. Thoracic Surg. 11: 388-395, 1942.
10. Neuhof, Harold, and Aufses, A. H.: Cancer of the Lung. Interval and Late Results in Relation to Topography and Gross Pathology, J. Thoracic Surg. 17: 297, 1948.
11. Ochsner, Alton, DeBakey, Michael, and Dixon, J. L.: Primary Carcinoma of the Lung, J. A. M. A. 135: 321-327, 1947.
12. Ochsner, Alton, DeBakey, M. E., and Dixon, J. L.: Primary Pulmonary Malignancy Treated by Resection, an Analysis of 129 Cases, Ann. Surg. 125: 522-540, 1947.
13. Rienhoff, W. F., Jr.: The Present Status of the Surgical Treatment of Carcinoma of the Lung, Ann. Surg. 125: 541-565, 1947.
14. Schafer, P. W., and Scott, O. B.: Should Solitary Pulmonary "Metastases" Be Resected? J. Thoracic Surg. 16: 524-529, 1947.

SURGICAL TREATMENT OF CONGENITAL CYSTIC DISEASE OF THE LUNG WITH A REPORT OF TWO CASES

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A DECADE ago, congenital cystic disease of the lung had a formidable prognosis. In a review up to 1935, Schenck and Stein[28] stated that although adults might live for many years with pulmonary cysts, the condition in children and infants carried the gravest outlook and early death was frequent. In an analysis of fifty-one reported cases in infants and children from 1925 to 1935, thirty-five of the patients, or 69 *per cent,* were dead. Schenck and Stein concluded, "No specific treatment can be offered. Many cases present a surgical problem and future thoracic surgery in infants and children must meet the challenge." Chemotherapeutic agents have altered the prognosis, but the disease and its various complications remain in the realm of thoracic surgery.

In 1943, seven years after the review by Schenck and Stein, Fischer and associates[9] reported a successful lobectomy for congenital cystic disease of the lung in a 4-week-old infant and stated they were unable to find by "close study of the literature" any previously reported successful cases of lobectomy in so young a patient. Gross,[4] in 1946, reported a successful pneumonectomy for pulmonary cysts in a 3-week-old infant. There are few other reports of excisional surgery for this disease in infants. Smith,[18] in 1942, reported a successful lobectomy by Churchill in a 19-month-old infant. He stated, "It is believed that competent surgery offers the best opportunity for cure when the disease is of clinical importance, when discovered early, when localized . . . and when, in certain cases, sufficient time has elapsed that the natural restoration of function seems unlikely."

The present paper is concerned with a report of two cases of congenital cystic disease of the lung which had successful extirpative surgery. One was an infant of 11 weeks who underwent a lobectomy. The other was a boy of 4 years, upon whom a total pneumonectomy was performed. Because of the small number of patients successfully operated upon reported among infants and children, the present two cases are considered statistically worthy of report.

CASE REPORTS

Case 1.—A white baby boy, J. P., was born on March 25, 1947, of a normal primigravida in the thirty-fourth week of gestation at the Methodist Hospital, Brooklyn. Birth weight was 4 pounds 13 ounces. On the third day of life, the baby became cyanotic after a gavage feeding. X-ray examination revealed what was believed at the time to be an atelectatic right upper lung (Fig. 1). For the next three days, the infant exhibited episodes of cyanosis and coughed up blood-tinged, mucinous material. During this period, he was supported by oxygen, parenteral fluids, antibiotics, and incubator care. Recovery was progressive, and, as the "atelectatic" process of the right upper lung resolved, it became

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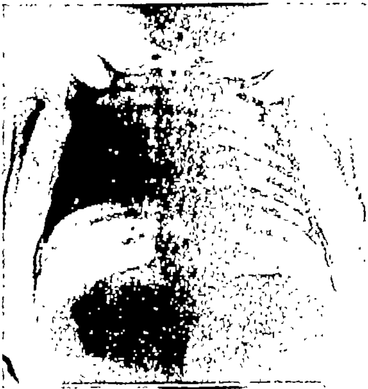
apparent that cystic cavitation replaced the lung tissue in this area. He was discharged from the hospital at 5 weeks of age, weighing six pounds, and in good health.

Three weeks later, the patient was readmitted with marked respiratory distress and signs suggesting a tracheobronchitis and consolidation of the right upper lobe. Roentgenogram showed a reaccumulation of fluid in the previously described cavernous area, with surrounding inflammation. Resolution with residual cystic loculation occurred by the twelfth day (Figs. 2, 3). The pediatrician (S. E. P.) requested a consultation, and it was decided that surgery offered the best hope for an ultimate, favorable prognosis.

Operative Procedure.—June 11, 1947, the pleural cavity was entered through the right second anterior intercostal space by the senior author, at the Methodist Hospital. The

Fig. 1.



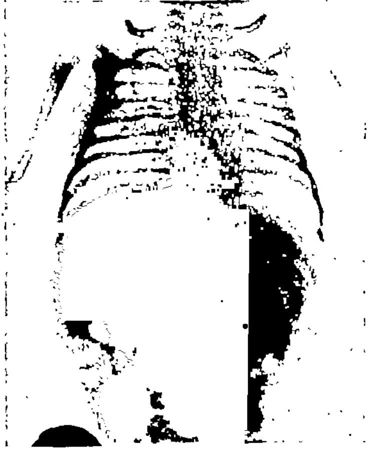


Fig. 2.

Fig. 1 (Case 1).—First x-ray film from which diagnosis of atelectasis was made.

Fig. 2 (Case 1).—Preoperative roentgenogram showing cystic disease in right upper pulmonary field.

right upper lobe was found to be the site of extensive cystic disease with evidence of recent pneumonitis. An interesting finding was the presence of an extrapulmonary cyst between the upper and middle lobes. It was enucleated separately. A right upper lobectomy was performed; the lobe bronchus was too small and friable to close in the usual manner and it was closed with simple transfixion ligation of fine silk, after individual ligation of the vessels. The middle and lower lobes appeared normal. The chest wall was closed anatomically and intercostal underwater drainage instituted. The remaining lung tissue was seen to obliterate the pleural space and the tube was removed on the second postoperative day. The hospital course was uneventful and the infant was discharged on the eighth postoperative day, weighing eight pounds.

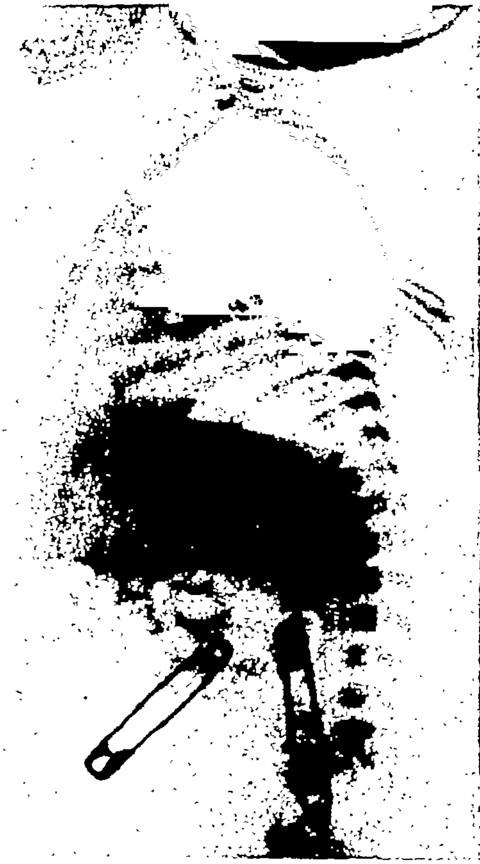


Fig. 3.

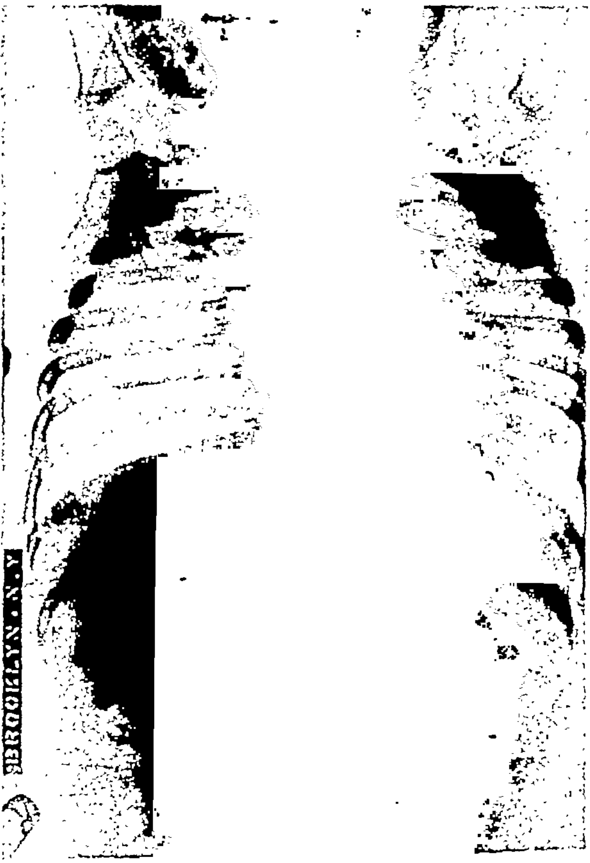


Fig. 4.

Fig. 3 (Case 1).—Lateral view taken preoperatively.
Fig. 4 (Case 1).—Chest film taken eight months postoperatively.

Microscopically, the cystic structures were seen to be composed of fibous tissue lined with columnar ciliated epithelium characteristic of bronchial mucosa. The surrounding pulmonary tissue was atelectatic and the site of pneumonitis.

On follow-up, sixteen months later (November, 1948), the infant was in good health and weighed 28 pounds. A check-up chest film revealed normal findings (Fig. 4).

CASE 2.—A boy, R. K., was admitted to Peck Memorial Hospital, Brooklyn, for the first time on March 4, 1946, at the age of 2½ years. The chief complaint was cough and crampy abdominal pain for five days, marked by a temperature of 105° F.

Past history revealed an uncomplicated birth. At the age of 23 months, on Aug. 31, 1945, the child suffered an electric shock. He was rendered unconscious and was hospitalized

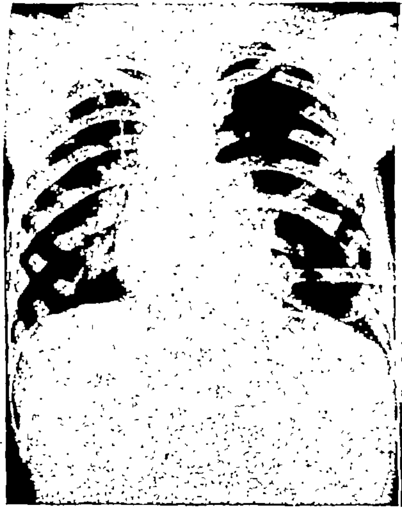


Fig. 5.

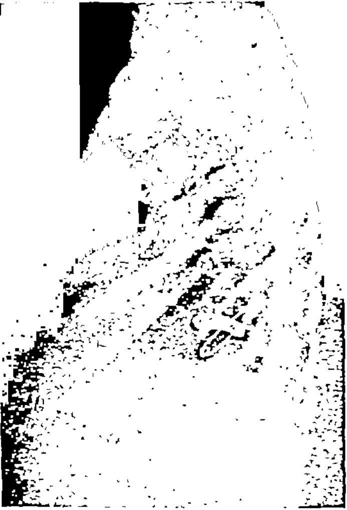


Fig. 6.

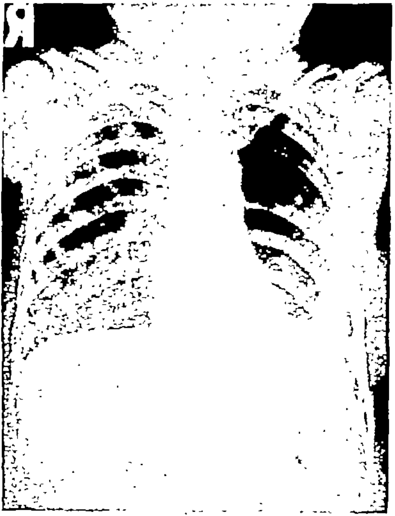


Fig. 7.

Fig. 5 (Case 2).—Prepneumonectomy roentgenogram showing catheter within large cyst of left lower lobe. Upper lobe cysts do not show well.

Fig. 6 (Case 2).—Lateral view taken before definitive surgery. The cystic disease of upper lobe is better visualized here.

Fig. 7 (Case 2).—Postoperative x-ray film showing absence of left lung and mediastinum in midline.

for one day. He was discharged with a diagnosis of electric shock and burns. At this time, no abnormality was noted relative to the lung and, unfortunately, no chest film was taken.

For a month prior to the 1946 Peck Hospital admission, the child had exhibited easy fatigability. He did not elect to climb stairs and his play tolerance had become short.

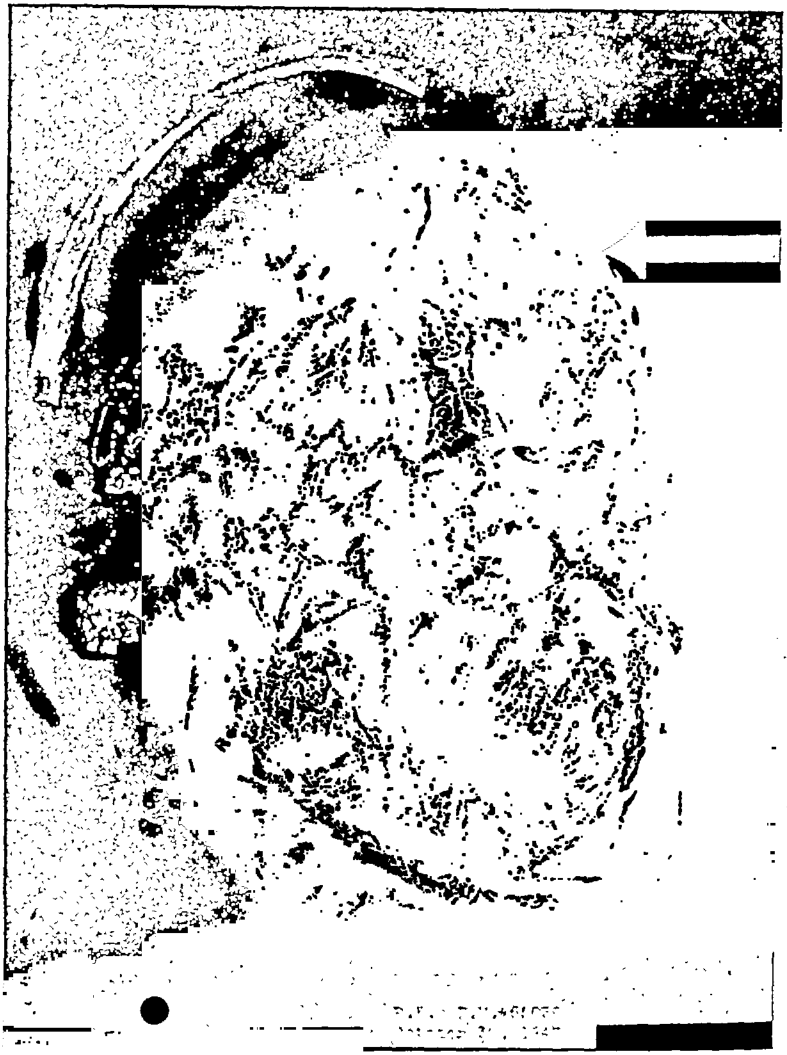


Fig. 8 (Case 2).—Photograph of pathologic specimen. The larger lower cyst is readily seen. The arrow points to one of the smaller cysts.

Physical examination revealed suppressed breath sounds in the left lower lobe and a shift of the heart to the right. Chest x-ray film showed gross distortion of the intrathoracic viscera due to a large ovoid lung cyst, measuring 6 by 7.5 cm. which crowded the entire base of the left lung and displaced the heart at least 3 cm. to the right. There was also another cavitation in the left apex which appeared triangular in shape. There was evidence of pneumonitis surrounding the cysts. The inflammatory component responded to treatment, but the tension cyst produced progressive mediastinal shift and severe restriction of activity. It was decided that decompression of the cyst was necessary before definitive surgery could be performed.

On April 22, 1946, a rib resection was performed (by A. J. V.) removing two inches of the eighth rib directly over the large lower cyst. The wound was packed and, four days later, the cyst was opened, with excision of a section of the wall for pathologic study. A thoracotomy tube was inserted into the cyst and subsequently the mediastinum shifted to the left sufficiently to allow the child to be normally active (Figs. 5, 6).

The tissue was reported as "congenital bronchiolitic cyst."

The child left the hospital in good condition, with the tube in situ.

During the following eighteen months, he led a more or less normal life, and developed fairly normally, although he remained underweight.

On Oct. 28, 1947, the child was readmitted to the Carson Peck Memorial Hospital for definitive surgery. A total left pneumonectomy was performed by one of us (E. H. G.).

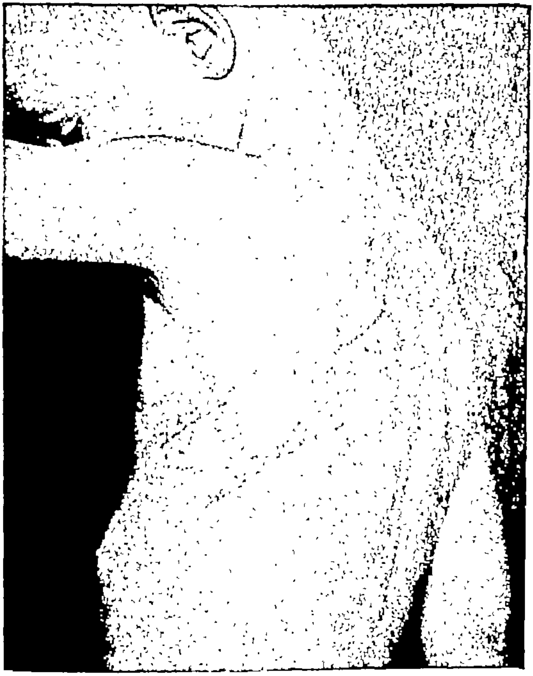


Fig. 7 (Case 2).—Photograph of patient, showing pneumonectomy scar and closed thoracotomy wound.

The fifth rib was resected subperiosteally and the pneumonectomy done by dividing the hilar structures first and the fistulous tract last. The cutaneous opening of the fistulous tract had been sealed off prior to the opening of the chest cavity. After excision of the tract, the main wound was closed with interrupted silk sutures in layers. Penicillin, 400,000 units, and 1 Gm. streptomycin were placed in the left chest cavity through a catheter which was removed as the last suture was tied. The cutaneous component of the previous thoracotomy wound was closed in layers after sealing off the main pneumonectomy wound. No drainage was used (Fig. 7).

The pathologic report was diffuse congenital cystic disease of the left lung with intervening atelectasis and pneumonitis (Fig. 8).

The child was discharged from the hospital on the seventeenth postoperative day in good condition (Fig. 9). It is now thirteen months (November, 1948) since the pneumonectomy. The child lives a normal life. He is extremely active. He is now 4½ years old and is growing at a normal rate.

COMMENTS

Complications of congenital cysts are of three kinds. The first is infection of the cyst wall or suppuration within the lumen. This may be of serious nature. The patient in Case 1, although only 11 weeks of age at the time of operation, had had two critical episodes of suppurative disease.

The second complication is altered physiology as seen in Case 2. Cysts may be connected to the respiratory tract by relatively small or angulated passages, so that air enters, but becomes entrapped. Thus, a positive pressure can be built up within the cyst, so that the structure becomes greatly distended and compresses adjacent lung tissue and mediastinal organs to the opposite side of the chest. Because of this, respiratory distress can be so extreme that the situation may be incompatible with life unless some form of relief is promptly instituted. This complication led to preliminary decompression in the second case.

The third type of complication is rupture of the cyst into the pleural cavity with possible tension pneumothorax and empyema.[8]

DISCUSSION

Numerous excellent reviews of cystic disease of the lung have appeared in the now voluminous literature of the subject.[10, 11, 21, 27, 28, 33, 35] We shall limit our discussion to congenital cysts. Acquired, dermoid, echinococcal, cysts of indeterminate origin, and rarer ones such as aberrent gastric cysts are not within the scope of the present paper.

Congenital cysts are less common than acquired cysts which appear as a consequence of inflammatory reactions. Congenital pulmonary cysts may be single or multiple, localized or scattered; they may or may not communicate with a bronchus and may contain fluid, gas, or both.[15, 30] Such an abnormality of the lung may arise as a solitary structure from an accessory bronchial bud. The cyst may appear as a pedunculated affair, situated between pulmonary lobes or else projecting in front of or behind the lung root. Such a solitary lung cyst was found between the upper and middle right lobes in Case 1. This was in addition to a diffusely cystic upper lobe. More frequently, however, cysts develop within the parenchyma and under such circumstances they are quite likely to be multiple. This was true of the second case. Congenital lung cysts are occasionally bilateral, but, fortunately, they are more often limited to one lung.

Whereas acquired cysts presumably do not appear until early childhood at the earliest, it is conceivable that tissue predisposition, i.e., weakness of the elastic or muscular layer of the bronchus,[40] may lead to cystic malformation at a very early period. Thus, some forms of cystic disease—localized cystic bronchiectasis, for example—might be considered congenital if they appear in early infancy and acquired if the tissues withstand the strains for a longer period of time. Certain pathologic considerations[9] fortify this concept. Most pathologists consider any cyst lined with a bronchial epithelium, the individual cells of which are mucus-secreting, ciliated and columnar in type, as congenital in nature.

Congenital cysts are usually bronchial in origin[3, 6, 12, 26, 30] but rarely may be enterogenous[14] or lymphangiomatous.[30] Anspach and Wolman[30] reviewed the theories of pathogenesis prevailing in 1933 and suggested that most congenital cysts are fluid-containing at birth and frequently rupture or spill over into a bronchus after birth, becoming air-filled cavities. The clinical course and x-ray findings of Case 1 would suggest this turn of events.

The symptomatology of a given cyst depends on the original anatomical status together with postnatal changes affected by respiratory action and infection. A small cyst may give no signs or symptoms and occasionally larger cysts may persist into adult life before their presence is suspected.[6, 25] The pattern described by Anspach and Wolman has been followed, generally, in the subsequently reported cases and was true of our two cases.

The physical signs, depending on the stage and type of pathology, are, of course, extremely variable. Schenck[24] has tabulated the signs and symptoms and their relative frequency. These included almost everything that can be imagined as occurring with disease of the lung.

The x-ray features of congenital cystic disease of the lung have been described by many competent observers.[22, 28, 30, 35] The problems of differential diagnosis are often considerable. Fluid-containing cysts, before rupture into a bronchus, and depending upon the element of infection, may suggest inflammatory consolidation, atelectasis, empyema, or even solid tumors. Atelectasis, as in the first case, is apparently the most frequently simulated picture. Air cysts, in which a fluid level may or may not be present, necessitate differentiation from obstructive emphysema,[17] bullous emphysema, loculated pneumothorax, hypropneumothorax, pulmonary abscess, acquired bronchiectasis, and tuberculous cavitation. In the neonatal period, the possibilities are limited and the roentgenologist, given a complete clinical history, can often make the diagnosis.

Boyd,[40] in his sixth edition of *Surgical Pathology* (1947), states, "It is not possible to write a satisfactory account of cysts (congenital) of the lung for the pathology is so confused." A review of the literature would seem to indicate that the difficulty arises out of the fact that the original anatomy, which includes variable degrees and patterns of congenital deformity, may be altered by mechanical factors or infection either alone or in combination. Through all of the controversy, there is but one pathologic feature more or less universally accepted, that the type of lung cyst which develops from a bronchial bud is of necessity, at least in its primordial state, lined with mucus-secreting, ciliated columnar epithelium, characteristic of bronchial mucosa. Most recent authors insist upon this as the basic histologic feature of an undisputed congenital cyst.[3, 4, 5, 9] Variations and all gradations from the typical to a flattened cuboidal type of epithelium have been described.[6, 10, 20, 40] It is understandable that infection might destroy the original epithelium and replace it with granulation tissue and eventually with a less characteristic cell type. The walls and supporting stroma of the cysts have also been variously described and, unfortunately, the few reports of pulmonary cysts in stillbirths[39] do not solve the problem because of developmental factors and the variety of findings which might be postulated. Dickson and associates[3] (1946), in reviewing the histologic features of twenty-two pulmonary cysts, suggest that disorderly arrangement and erratic grouping of the supporting stromal structures (cartilage, smooth muscle, elastic tissue, and glands) are characteristic of most congenital cysts. They constrast the extreme variability of the supporting tissues and the frequent dominance of one or the other of the stromal elements in the congenital cyst with the orderly arrangement of these structures in simple bronchial dilatation. It is of significance, however, that their youngest patient was 7 years of age and that all but three of the twenty-two cases showed signs of infection. They readily concede that absolute classification is difficult and, at times, impossible because of the interplay of congenital and acquired factors.

Various forms of surgical therapy have been employed. A needle can be passed through the chest wall into the cyst cavity permitting withdrawal of entrapped air. Improvement is likely to be immediate and dramatic but it is temporary, as the air will again accumulate. Furthermore, a connection to the pleural space may be made and a tension pneumothorax result. Aspiration, with a fine needle, should be employed only as a temporizing measure, while preparing for more adequate therapy.

A trocar may be employed through which a catheter is threaded for the establishment of more prolonged aspiration. In this form of therapy, it is preferable to use a small mushroom catheter so that its bulbous end can be pulled against the inside of the cyst wall preventing escape of air into the pleural space.[4] Constant application of suction should keep the cyst completely collapsed. This is of value in preparing for more extensive surgery. One of us (A. J. V.) elected a modification of this method to bring the second of our cases to definitive excisional surgery in the best possible condition. The use of sclerosing fluids is precluded by the possibility of communication of the cyst with a bronchus.

Marsupialization of the cyst onto the chest wall with destruction of its membrane by curettage, cauterization, or packing has points in its favor. The external opening, however, produces considerable danger. Infection may gain entrance to the regional lung, a problem which would be difficult to control. The greatest objection to the method is that congenital cysts are prone to be multiple. Hence, marsupialization should be practiced only when the surgeon is certain he is dealing with a solitary cyst.

Enucleation of the cyst or the removal of pulmonary tissue is by far the treatment of choice. Segmental resection, lobectomy, or even total pneumonectomy may be necessary. In Case 1, right upper lobectomy and enucleation of an extrapulmonary cyst were sufficient. In Case 2, a left total pneumonectomy was necessary to remove all the pathology. The presence of a bronchocutaneous fistula in this case presented an added technical difficulty.

Anomalous blood vessels are frequently associated with congenital cystic disease. They may be of considerable caliber and are notoriously variable in origin, even transversing the diaphragm to take an anomalous position in the thorax. It is of prime importance that the thoracic surgeon dealing with the excision of cystic disease of the lung should be cognizant of these facts. Adhesions in a location usually divided with impunity may conceal large vessels; if these are not ligated, the operation would prove disastrous.

SUMMARY AND CONCLUSIONS

Two cases of successful excisional surgery for congenital pulmonary cystic disease are presented. The first case is a lobectomy in an 11-week-old baby. The second case is a left total pneumonectomy in a 4-year-old boy.

The literature is reviewed. The diagnosis, symptomatology, pathogenesis, pathology, complications, and treatment are discussed.

Excisional surgery, we believe, is the treatment of choice in congenital cystic disease of the lung. Infants and young children withstand thoracic surgery well.

REFERENCES

1. Klosk, Emanuel, Bernstein, A., and Parsonnet, A.: Cystic Disease of the Lung, Ann. Int. Med. 24: 217, 1946.
2. Gross, R.: Cystic Disease of the Lung, Clin. Proc. Child. Hosp. 2: 212, 1946.
3. Dickson, James A., Clagett, T. O., and McDonald, J. R.: Cystic Disease of the Lungs and Its Relationship to Bronchiectatic Cavities, J. Thoracic. Surg. 15: 196, 1946.
4. Gross, R. E.: Congenital Cystic Lung; Successful Pneumonectomy in a 3-Week-Old Baby, Ann. Surg. 123: 229, 1946.
5. Savain, W., and Bryant, E.: Congenital Cystic Disease of the Lung, Radiology. 47: 166, 1946.
6. Phillips, Eileen, and Stewart, C. A.: Annular Areas of Pulmonary Rarefaction in Children, New Orleans M. & S. J. 98: 247, 1945.
7. Allende, J. M., Caeiro, A. and de Goycoechea, O. L.: Actual Concepts on the Surgical Management of some Pulmonary Conditions, Prensa med. argent. 31: 18, 1944.
8. Carson, M. J., and Webb, A.: Congenital Lung Cyst Complicated by Pyopneumothorax, J. Pediat. 25: 443, 1944.
9. Fischer, Carl C., Tropea, Frank, and Bailey, Charles P.: Report of an Infant Treated by Lobectomy With Recovery, J. Pediat. 23: 219, 1943.
10. Willis, F. E. S., and Almeyda, J.: Cystic Disease of the Lung, Tubercle. 24: 27, 1943; Tubercle. 24: 43, 1943.
11. Ruschin, Louis J.: The Cystic Lung, California & West. Med. 59: 62, 1943.
12. Rigler, L. G.: The Infected Lung Cyst, Radiology. 40: 485, 1943.
13. Smith, W. A.: Cystic Disease of the Lung; A problem in Differential Diagnosis. Internat. Clin. 1: 144, 1942.
14. Ward, I. M., and Krahl, J. B.: Enterogenous Pulmonary Cyst, Am. J. Dis. Child. 63: 924, 1942.
15. Rigler, L. G.: Cystic Disease of the Lungs, Internat. Clin. 4: 203, 1941.
16. Nalls, W. L., and Cole, D. B.: Cystic Lung Disease: A Report of two Cases With Autopsy Findings, Virginia M. Monthly 68: 394, 1941.
17. Caffey, J.: Regional Obstructive Pulmonary Emphysema in Infants and Children, Am. J. Dis. Child. 60: 586, 1940.
18. Sante, L. R.: Cystic Disease of Lung, Radiology. 33: 152, 1939.
19. Weaver, R. G., and von Hamm, E.: Cystic Disease of the Lung, Surgery 4: 917, 1938.
20. Ford, F. A.: Congenital Cystic Disease of the Lung in New Born Infant, Radiology. 30: 248, 1938.
21. Cole, D. B., and Nalls, W. L.: Congenital Cystic Lung Disease, J. Lab. & Clin. Med. 23: 1111, 1938.
22. Wood, Harry C.: Congenital Cystic Disease of the Lung, J. Thoracic Surg. 6: 634, 1937.
23. Lereboullet, P., Lelong, M., and Bernard, J.: Emphysema With a Solitary Large Bulla Simulating a Large Congenital Cyst of the Lung in a Nursling of Four Months. Bull. et mém. Soc. méd. d. hôp. de Paris. 53: 506, 1937.
24. Peirce, C. B., and Dirkse, P. R.: Pulmonary Pneumatocele, Radiology 28: 651, 1937.

25. Bezancon, F., DeLarue, J., and Arribehante, R.: Tuberculization of a Large Congenital Cyst of the Lung in a Nursling. Ann. d'anat. path. 14: 642, 1937.
26. King, J. C., and Harris, L. C.: Congenital Lung Cyst, J. A. M. A. 108: 274, 1937.
27. Oughterson, A. W., and Taffel, M.: Pulmonary Cysts, Yale J. Biol. & Med. 9: 77, 1936.
28. Schenck, S. G., and Stein, J. L.: Congenital Lung Cysts in Infants and Children, Radiology 24: 420, 1935.
29. Dubrow, James L.: Congenital Cyst of the Lung, Radiology 24: 480, 1935.
30. Anspach, William E., and Wolman, Irving J.: Large Pulmonary Air Cysts of Infancy; With Special Reference to Pathogenesis and Diagnosis, Surg., Gynec. & Obst. 56: 635, 1933.
31. McNeil, C., MacGregor, A. R., and Alexander, W. A.: Studies of Pneumonia in Childhood, Arch. Dis. Childhood. 4: 12, 1929.
32. Jackson, C.: The Mechanism of Physical Signs in Neoplastic and Other Diseases of the Lung, J. A. M. A. 95: 639, 1930.
33. Wolman, I. J.: Cystic Malformations of the Lungs, Brennemann's Practice of Pediatrics, Vol. 2, Chap. 47, Hagerstown, Md., 1947, W. F. Prior Company, Inc., p. 10.
34. Schenck, S. G.: Diagnosis of Congenital Cystic Disease of the Lung, Arch. Int. Med. 60: 1, 1937.
35. Stanford, W. R., and Nalle, B. C.: Some Notes on Cystic Disease of the Lungs With a Report of One Case, Ann. Int. Med. 17: 65, 1942.
36. Gruenfeld, G. E., and Gray, S. H.: Malformations of the Lung, Arch. Path. 31: 393, 1941.
37. Moore, R. A.: Textbook of Pathology: On Cystic Disease of Lung, Philadelphia, 1944, W. B. Saunders Company, p. 869.
38. Wolman, I. J.: A Case of Congenital Cystic Lung in a Stillborn Fetus, Bull. Ayer Clin. Lab., Pennsylvania Hosp. 2: 49, 1930.
39. Koontz, A. R.: Congenital Cysts of the Lung, Bull. Johns Hopkins Hosp. 37: 340, 1925.
40. Boyd, W.: Surgical Pathology: On Cystic Disease of Lung, Philadelphia, 1947, W. B. Saunders Company, p. 799.

SURGICAL WOUNDS OF THE LUNG

The Mode of Healing of Pulmonary Tissue

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STRUCTURAL changes in the lung have been clearly described in infectious and neoplastic diseases of the lungs. Such is not the case, however, in pulmonary trauma due to accidents or surgical interference. A diligent search in the medical literature revealed very little work done on the subject. In 1929, Olch and Ballon[1] described the development of scar tissue on the lung resulting from experimental wounds. No other paper appeared until 1944 when Montgomery[2] described the mode of healing of experimental wounds of the lung. More recently, Porter, Higgins, and Claggett[3] reported, in abstract, experiments carried out on this field. The complete article, as far as we know, has not, as yet, appeared in any publication.

A number of related articles dealing with the pathologic physiology of the lung are worth mentioning. The monograph of Cecil K. Drinker[4] on pulmonary edema describes beautifully the role of capillary anoxia in the diffusion of exudates from the alveolar capillaries into the alveoli. Macklin's[5] description of tracheobronchial musculature and the physiologic mechanisms involved in normal respiration, as well as in pathologic states, is worthy of mention. The basic facts concerned in wound healing described by Arey,[6] though not directly concerned with changes in the lung, may well be applied to healing of pulmonary tissue. The role of phagocytosis in the handling of foreign material in the lung has been aptly discussed by Robertson.[7]

In thoracic surgery a great deal of progress was made since the report of Graham[8] on a successful pneumonectomy for carcinoma of the lung. A great step forward was made by Blades and Kent[9] with the individual ligation technique for pneumonectomy. The covering of the bronchial stump with pleura has prevented a large number of annoying and even fatal bronchial fistulas in the patients requiring a total pneumonectomy. Patients who may require only a subtotal pneumonectomy generally do very well if some pulmonary tissue is left to be used as a covering pad of the bronchial stump.[10] Not all pathologic states in the lung require complete resection of the lung and techniques have been described even for segmental resection of the lung.[11] We have felt for many years that surgery of the lung, unless definitely indicated, need not be too drastic or mutilating.

In benign lesions every effort ought to be made to preserve as much normal lung as possible for future necessities. The less normal lung necessarily is sacrificed, the more lung is left to serve for the general economy of the patient for future emergencies.

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With this principle in mind we carried out a series of experiments over a period of years in the hope of determining what happens to the remaining portion of the lung which has been operated upon, after surgical trauma and suture. We studied the effects of such injuries as crushing and puncture wounds, tears, incisions, resection of wedges of lung, and finally resection of lung tissue at right angles to the axis of the bronchovascular elements. We also studied the response of the lung to absorbable and nonabsorbable suture material. The effects of these procedures were studied by sacrificing the animal immediately after the experiment, at 90 minutes, at 24 to 30 hours, at 48 hours, at 5 to 7 days, at 10 to 14 days, at 1 month, at 6 months, and at periods of four years or longer.

The peculiar structure of the lung is instrumental in the development of certain basic changes resulting from injury or infection. Anatomically the lung is so constructed as to expose as much of the capillary blood supply as possible to the alveolar vapors. Because of this fact, the human lung is made up of approximately 750 million alveoli which are connected with the atmospheric vapors through the tracheobronchial tree. The vascular and lymphatic supply of the lung follows much the same pattern of distribution as the tracheobronchial tree.[4] The capillary distribution of the alveoli is so constructed that an enormous amount of blood is present in the lung at any one given time. By means of surface stereomicroscopic studies on the alveoli of living dogs, frogs, and alligators, we learned[12] that the alveolar wall is practically flooded with blood in the one-cell capillaries which drain the blood into larger venous capillaries at the interalveolar junction. This is also true in the intra-alveolar septa that project into each alveolus. These capillaries connect with the larger ones at the interalveolar junction. The flow of blood is in one direction and gives the impression of waves seen in wheat fields when the wind blows over them.

The lung having one root at the primary bronchus may be considered fan shaped if we can imagine a fan projecting in all directions and planes. Because of this structural pattern, any distortion of the normal contour of the lung has a tendency to bring the bronchi and vessels in closer apposition and thus these elements assume a contour of a number of strands bunched together. In our description of this pattern we shall refer to this change as *strand formation.*

The lung has all the opportunities for proper drainage through the tracheobronchial tree. With the exception of the interstitial tissue, it is exposed to the atmosphere. In the absence of bronchial occlusion most foreign particles, including pus, may be expelled by cough or postural drainage. Furthermore, the tracheal mucosa is covered with ciliated mucous epithelium. This pattern extends down to the respiratory bronchioles.[5] The cilia have a very active upward movement and may aid in directing toward the trachea any particulate matter or mucus that finds its way into the respiratory passages. The goblet cells of the mucous layers of the epithelium assist in this process by lubricating the foreign particles with mucus. The extensive musculature of the bronchi, by narrowing and dilating the lumen and by elongating and shortening the bronchial trunk, do their share in eliminating noxious matter that may find its way into the respiratory passages. The act of coughing plays a very important role in the expulsion of noxious matter from the tracheobronchial tree.

The treelike branching of the bronchi and the blood vessels is terminal. There is no collateral branching. It is for this reason that occlusions of bronchi generally result in atelectasis. By the same token occlusions of the vessels result in local blocking of the blood supply to cause infarction.[15] The presence of alveolar pores has been described and was given as a means of collateral respiration. Such pores, however, are not sufficient to take care of large groups of alveoli, especially those arising from a bronchus independent of the one supplying air to a given area.

In our work we have found that the lung produces a thick, gummy, yellowish secretion which serves to plug up lacerated or injured alveoli and small bronchi. This secretion will plug up the lung tissue so that in a short time air leakage may stop. This process is enhanced by the contraction of the lung which follows when air finds its way into the pleural cavity.

Healing of lung tissue is so prompt that many minor injuries occurring in the lung heal without even producing clinical symptoms. For example, when a small perforation occurs in the lung from a rupture of a pleural bleb or a puncture of the lung surface with a needle (as in the case of artificial pneumothorax) air escapes into the pleural cavity. This air is sucked out into the pleural space by virtue of the existing negative intrapleural pressure. The lung then begins to collapse and by doing so the alveoli are compressed, the bronchovascular elements contract and become more closely approximated. As the pulmonary tissue juices seal off the puncture wound, no more air or fluid exudes from the injured surface of the lung. Within five to seven days the repair processes have been completed. Coincidentally, the air in the pleural cavity is absorbed, the lung re-expands and functions as before. It is interesting to note that after seven days no evidence of injury may appear in the lung, except some local thickening of the visceral pleura.

If the lung is exposed by thoracotomy when such an injury occurs this process of healing may be facilitated by gently pressing the injured portion of the lung with the thumb and index finger or by a gentle stroking massage, with slight pressure over the denuded area, at the point of leakage. In this way, the alveoli become contracted and the pulmonary tissue juices seal off the alveoli, so that air leakage is eliminated. Such a seal becomes sufficiently secure to prevent further leakage even when the lung is distended to its normal volume immediately after the sealing process takes place. When the visceral pleura is completely sealed, the negative intrapleural pressure gradually allows air to be sucked into the contracted alveoli and a normal distention occurs.

If air is introduced into the lung under increased pressure, up to 60 mm. Hg, or more, then one or all of the following complications may develop[13]: 1. The intra-alveolar pressure may rise so high as to force air into the capillaries and result in air embolism. 2. The normal cohesive power of the visceral pleura may be overcome and a pleural bleb may result on the surface of the lung. If the tension is high enough to rupture the bulla, the air will leak into the pleural cavity and result in a pneumothorax. 3. If the intrabronchial pressure is unusually high (up to a maximum of 100 mm. Hg even for an instant) the hilar pleura may become detached and cause mediastinal, retroperitoneal, and interstitial emphysema. It is obvious, of course, that when a larger bronchus is injured only a suture of the bronchus can seal such a leak. When a fairly large bronchus is involved, the air continues to escape into the pleura and if the mediastinum is fixed and there is no ball-valve opening, the intrapleural pressure rises to a point equal to that of the intrabronchial pressure and thus the air leakage stops. If a small bronchus is involved, then the contraction of the lung along with the plastic pulmonary tissue juices results in an occlusion of the leaky bronchus. It is for this reason that the patient with a spontaneous pneumothorax may safely be left alone unless he has evidence of respiratory embarrassment. Thus, most cases of spontaneous pneumothorax clear up without aspiration of the air from the pleura provided the cough is controlled and thus increased intrabronchial pressure is eliminated.

EXPERIMENTS AND RESULTS

When the lung tissue is compressed gently with rubber-tipped clamps no appreciable changes occur. In this way, the lung may be sutured aseptically without the introduction of infected materials that may leak from the bronchi. However, if the lung is forcibly crushed by an artery forceps, a dent appears at the point of crushing. The proximal and the peripheral portions of the lung, on either side of the crush injury, contract and expand normally. If the intrabronchial pressure is increased, the dent will gradually disappear and the lung will assume grossly its original contour. All that remains on the surface is a pink line at the point of crushing. Increased intrabronchial pressure stretches the alveoli to their normal capacity.[14] This principle can be profitably utilized for the care of congestive changes of the lung causing consolidation as found in pneumonias. When the crushed alveoli are stretched to their normal volume, the microscopic appearance of the area reveals no deviation from the normal. If the alveoli are not distended, one can see a pool of red blood cells at the area of crushing with a definite line of demarcation between the crushed area and the normal structure (Fig. 1). The alveoli are completely filled with fluid and red blood cells. There is no evidence of inflammation immediately after crushing. After forty-eight hours one sees a diminution in the number of red cells and an increase in the amount of plasma. The changes are limited strictly to the area of crushing. By the fifth day the alveoli begin to show air intermingled with pools of red blood cells. By the tenth day the area appears completely normal except for some thickening of the interstitial elements.

When the lung is incised along the axis of the bronchovascular tree one may cut smaller vessels and bronchi which may run crosswise or obliquely at the incised area. In such a case the larger cut vessels and bronchi may be closed at the cut ends by ligature or suture and heal promptly. If, however, the bronchus or the nutrient vessel is ligated proximally en masse an atelectasis or infarction results in the peripheral portion of the lung. Such changes[15] may heal spontaneously or may result in an abscess and possible rupture of the lung (Fig. 2). When the lung is cut at right angles to the bronchovascular tree, the healing occurs without any possibility of infarction. It goes without saying that the proximal portion of the lung should be gently compressed with rubber-tipped forceps to avoid leakage of infected contents of the tracheobronchial tree into the sterile pleural cavity. The proximal stump may be sutured with a single or a double row of sutures of fine silk, plain, or chromic No. 00 or 0 catgut. Such a suture makes the stump airtight and watertight and when the lung is distended only the portion of the lung in the immediate vicinity of the suture does not contain air. If a wedge is amputated it is essential that the base be at the periphery of the lung and the apex be pyramided toward the base. In this way, the cut vessels and bronchi are only the ones supplying the wedge and have no peripheral connection with adjacent remaining lung.

When the animal is sacrificed immediately after the experiment one finds the alveoli at the site of the suture filled with red blood cells. There is a gradual diminution of the hemorrhagic changes immediately beyond the suture line and within 1 to 2 cm. the lung appears normal. Soon afterwards the blood elements and the capillary endothelium set up the processes of healing of the traumatized portion of the lung by organization of fibrin and subsequent steps of tissue repair.[6] Thickening of the interstitial elements occurs to a greater or less extent. The alveoli that have been filled with blood and plasma attempt to drain out their contents and begin to fill up with air. In ten days to two weeks, the traumatized areas show newly formed bronchial elements, some thickening of the interstitial tissue, and in four weeks there is a return to normal. In areas where the tissues are held by an unabsorbable suture the picture differs somewhat. Here the bronchovascular elements show strand formation between the sutures. The alveoli in such areas are smaller in size and their walls appear thickened (Fig. 3).

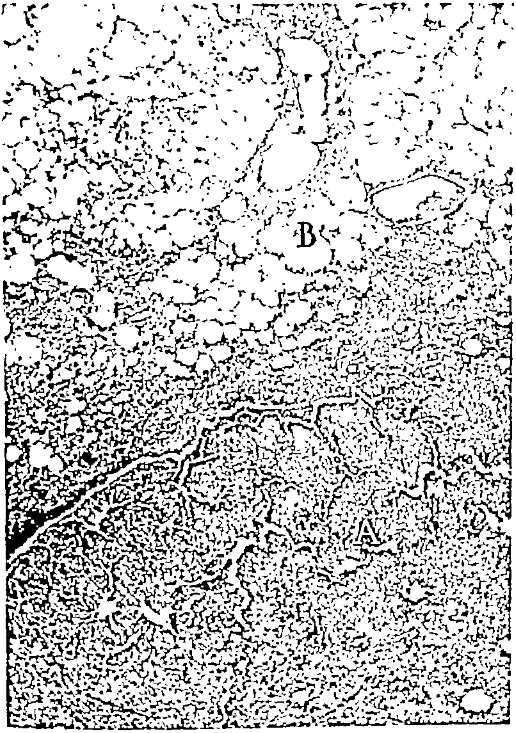

Fig. 1.—Microscopic section showing area of hemorrhage with a line of demarcation between normal (see *B*) and crushed lung (see *A*). (×45.)

In the analysis of the pulmonary response to trauma, the description of the microscopic findings under various procedures and at different time intervals may give a more clear-cut view.

In Experiment 95 the lung was crushed with a long artery forceps and immediately afterwards the lobe was resected. The crushed portion was not distended by increased intrabronchial pressure before the lobectomy. There was a dent at the site of the crush and both the proximal and distal portions appeared normal. The dented area was red and atelectatic. Microscopically, at the site of the crushing the alveoli contained no air but were filled with pools of red blood cells. On either side there was a gradual appearance of air-containing alveoli. Within a few millimeters beyond this area the lung appeared normal (Fig. 1).

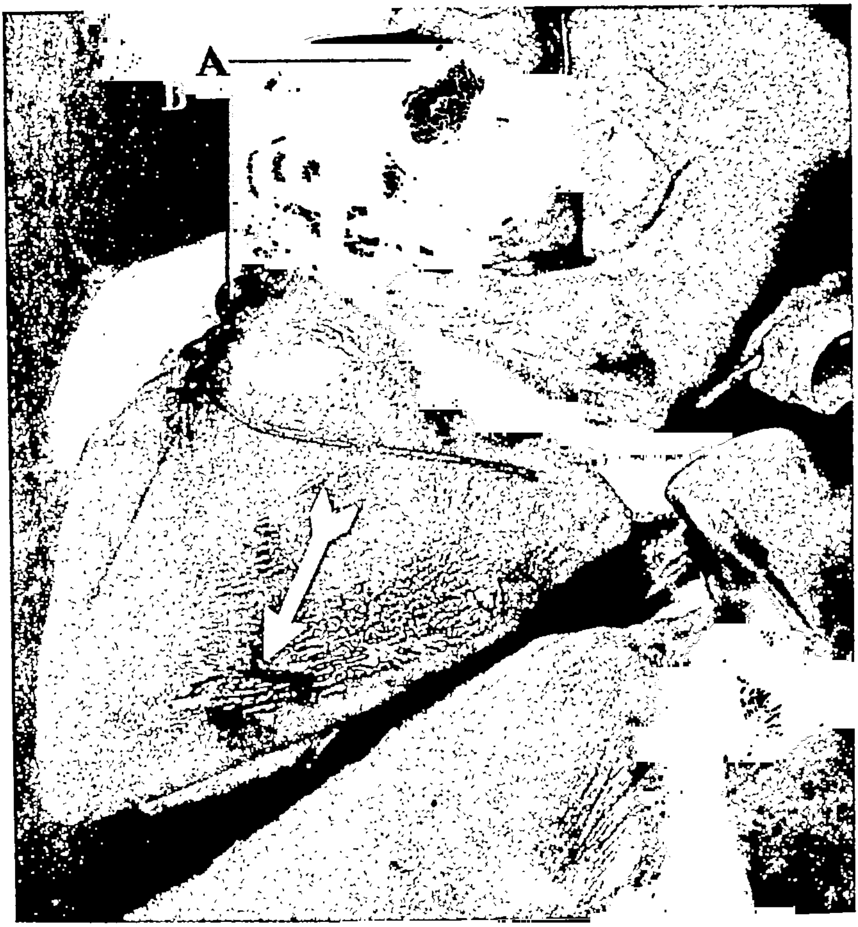

Fig. 2.—Gross specimen 27 hours after ligation of nutrient artery. Note area of infarct in tip of upper lobe (see *A*). Arrow shows effect of an incised wound on surface of lower lobe. Gentle pressure stopped leakage of air and blood. No suture applied. The area was completely airtight and watertight before closure of the chest cavity. Tip of lower lobe shows the effect of suture (see *B*).

In Experiment 97 the dog was sacrificed within ninety minutes. A left thoracotomy was performed under Nembutal narcosis and positive pressure artificial respiration. The tip of the left lower lobe was cut at right angles to the axis of the bronchovascular tree. This was done after gentle pressure was applied with a rubber-tipped intestinal clamp to control leakage of blood and air at a point well enough proximal to the site of amputation. A double row of continuous locking sutures with No. 0 size 10-day chromic catgut made the stump airtight and watertight. A wedge was also cut with the apex reaching close to the root of the lung and the base reaching the peripheral tip of the lung. The stumps on either side were sutured individually with a double row of fine silk sutures. The stumps were not approximated to one another. The chest was closed in layers and the air from the pleural cavity was aspirated just before the final skin sutures were applied. The dog showed no reaction or shock from the experiment. One and one-half hours after the experiment was finished the dog was sacrificed by injecting intravenously a lethal dose of Nembutal to cause a respiratory-center paralysis. Death occurred without any struggle on the part of the animal. In this way, no changes in the lung resulting from struggle had to be dealt with. We have found that even a mild struggle in the dog causes rupture of capillaries with resultant hemorrhages.[12] At autopsy the right lung appeared normal. The left lung at the site of the suture line showed the stumps to be liverlike in consistency and color (Fig. 2). The remaining lung appeared normal.

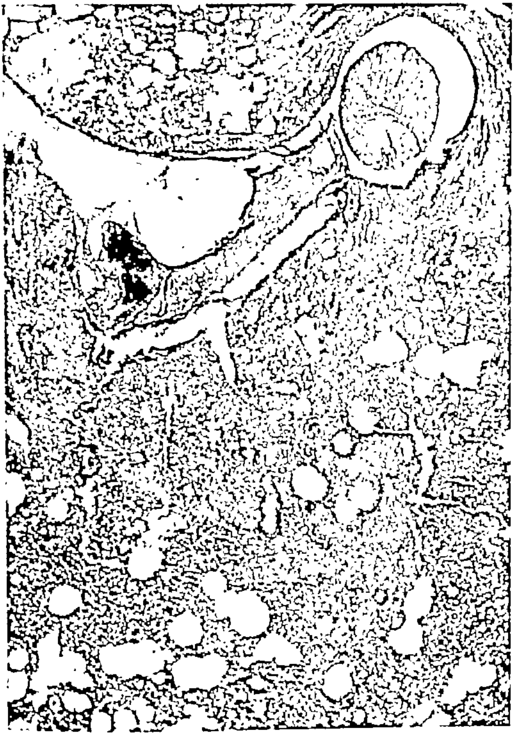

Fig. 1.—Appearance of the lung 90 minutes after suture. Note "strand formation" around the suture. The alveoli in the immediate vicinity are filled with blood elements. (×45.)

Microscopically, the sections from the stump of the lower lobe showed infiltration of the interstitial elements with areas of microscopic hemorrhages. The bronchovascular elements showed no appreciable change. There was atelectasis at the site of the suture but there were normal alveoli just beyond the sutures. In general, with the exception of islands of microscopic hemorrhages at the vicinity of the sutures and strand formation between the sutures, the lung appeared normal.

The sections of the stump of the upper lobe showed changes similar to those in the lower lobe. The bronchovascular elements around the suture showed strand formation in the direction of the pull of the two ends of the suture (Fig. 3).

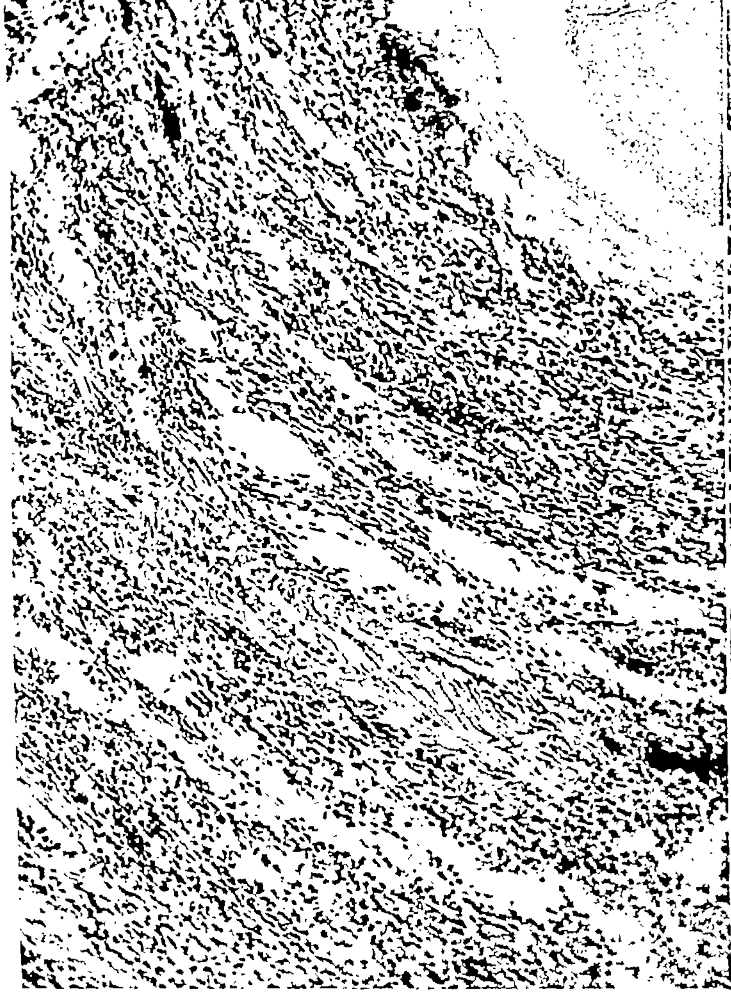

Fig. 4.

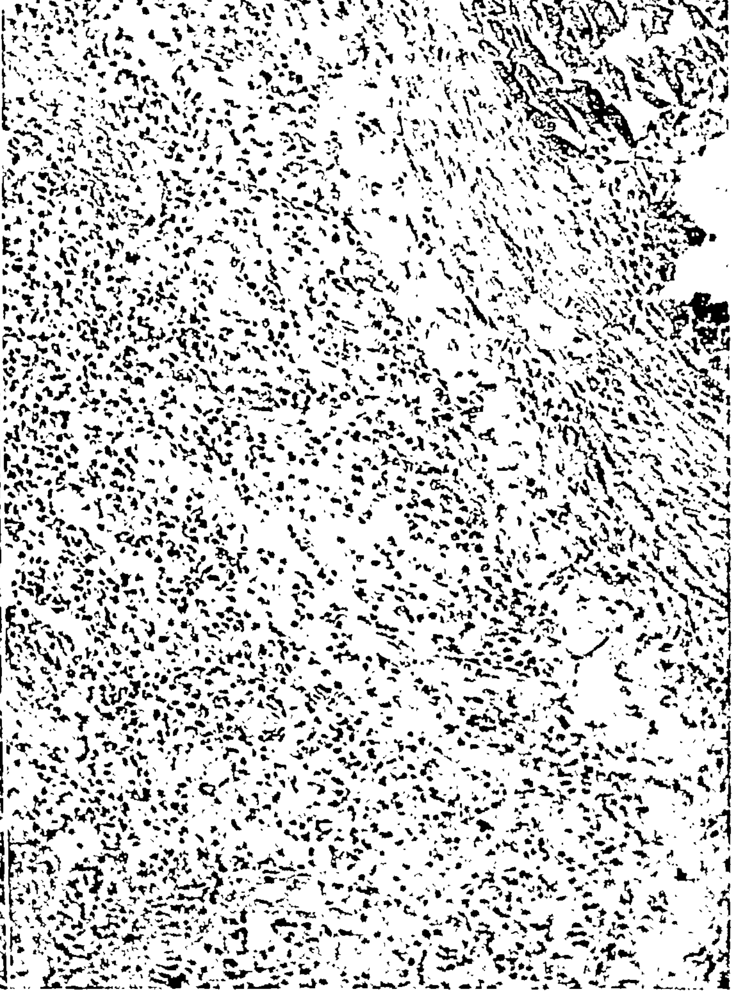

Fig. 5.

Fig. 4.—Appearance of the lung 48 hours after suture. At upper right-hand corner the suture is seen. Fibroblasts and collagen fibres may be clearly seen just beyond the suture. Normal alveolation is replaced by "strand formation." (×120.)

Fig. 5.—Appearance of lung 7 days after suture. At upper right-hand corner the catgut shows evidence of absorption. Immediately beyond the suture there is thick granulation tissue showing "strand formation." Just beyond this area fibroblasts and macrophages are seen in large numbers. Alveolation is quite evident. (×120.)

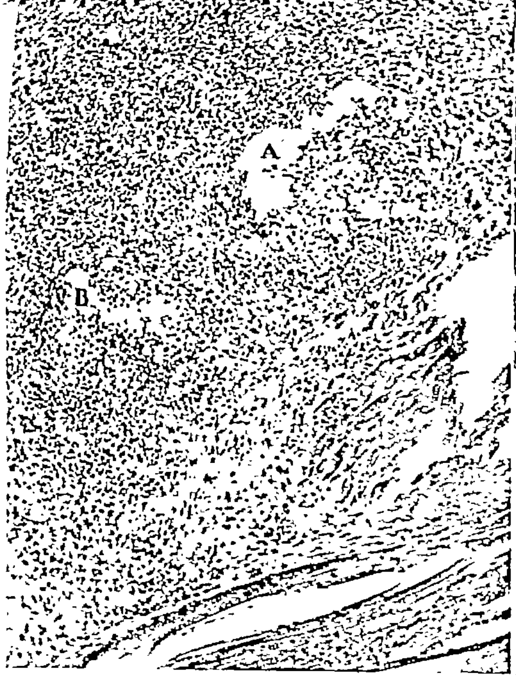

Fig. 6.

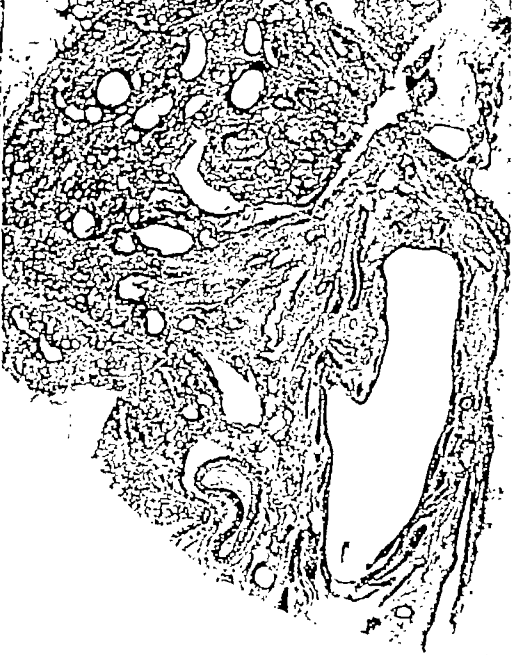

Fig. 7.

Fig. 6.—Appearance of the lung 14 days after suture. Note the fibers of catgut with phagocytes imbedded. At *A* and *B* the catgut is almost completely absorbed with the exception of a few particles of catgut containing phagocytes. Just beyond the suture the granulation tissue shows fibrous tissue development. (×120.)

Fig. 7.—Low-power appearance of a subtotal pneumonectomy stump four years after operation. Note the dimpling of the bronchial lumen and the distortion of the bronchi. Also note the dense fibrous tissue present between the bronchi. (×20.)

Experiment 98 was done to study the pulmonary stump at twenty-seven hours after the experiment. The tip of the left lower lobe was resected at right angles to the axis of the bronchovascular tree. A slit was made in the left upper lobe to a point where a larger vessel was cut. The vessel was ligated with a mass ligature well above the cut area. The cut edges were sutured with No. 00 chromic catgut. The upper portion of the lower lobe was incised with the scalpel on the outer surface and the incision was extended to a length of 3 cm. along the axis of the bronchovascular elements. Air bubbles and frothy contents appeared at the cut surface. After stroking the cut area with gentle pressure the air bubbles ceased to come through and the area was not distended further. At autopsy the right lung was normal. There was some injection of the dog's thin mediastinum. The left lung was adherent to the chest wall at the site of the thoracotomy by means of thin fibrinous adhesions. These peeled off easily. The tip of the upper lobe, where a mass ligature was placed, was purple in color, and liverlike. The tip of the lower lobe was normal except at the site of the suture line where it was atelectatic, dark red, but airtight and watertight. The site of the puncture showed no leakage of air or fluid and the cut edges were slightly separated from each other (Fig. 2). Microscopically, the area of surface tear showed a hemorrhage at the gap between the torn edges. Fibrin was present in the hemorrhagic area. The cut edges showed the alveoli and bronchioles filled with blood extending proximally for a few millimeters. From there on there was a gradual return to normal. The tip of the lower lobe showed strand formation in the direction of the pull from the sutures. The alveoli were compressed and filled with blood cells. The interstitial elements appeared to separate more and more from each other and assume a more normal pattern. The area of infarction showed complete filling of the alveoli with blood. The normal pulmonary pattern was gone. At the edge of the infarct there was a definite line of demarcation between the normal structure and consolidated area.

Another animal with a similar operation was sacrificed forty-eight hours after the experiment. The pleuropulmonary adhesions were still fibrinous in type. About 10 to 15 c.c. of thin bloody fluid in the chest were present. All sutures held well. The sutured area at the tip of the lung was lighter in color than at twenty-seven hours. The infarction in the upper lobe appeared similar to the findings at twenty-seven hours. Microscopically, the opposite lung showed areas of moderate emphysema. In an area between two sutures the interstitial elements were closely packed together producing strand formation in the direction of the pull from the suture. The alveoli were occluded and filled with some red blood cells and a few polymorphonuclear leucocytes. Fibroblasts were present in large numbers (Fig. 4).

After five to seven days the pleuropulmonary adhesions which are invariably present at the site of the thoracotomy became fibrous but still stripped easily. The pleura over the site of operation showed some thickening. The lung at the sutured area where the excision was done at right angles to the axis of the bronchovascular tree appeared normal. The consolidation was nearly gone. The bronchi showed some flattening or distortion but the lumen was intact and not completely occluded. In some areas the mucosa had papillary projections into the lumen. Newly formed bronchi were seen forming new air ducts between the new alveoli and the stem bronchus. In the immediate vicinity of the suture there was no tear in the lung. Just adjacent to the suture the strand formation persisted. Alveolation became more evident. The interstitial tissue was thickened. A large number of fibroblasts and macrophages were present. The alveoli were filled with serum and gradually integrated to the normal lung structure (Fig. 5).

By the fourteenth day most of the absorbable suture material dissolved, and the space held by the suture was filled with fibroblasts (Fig. 6). The smaller bronchi began to assume their normal contour. The alveoli showed aeration. There was an interalveolar wall thickening. In areas where the nutrient vessel had been blocked one might see evidence of fibrosis, or evidence of central breakdown with abscess formation.

Within four weeks' time the lung appeared normal except in areas containing unabsorbable sutures. The sutures remained intact. The strand pattern persisted around the suture and the interstitial tissue was thickened. The alveoli were small in the immediate proximity of the suture and gradually appeared larger till a normal pattern was reached at some distance from the suture. The portion of the lung operated upon is invariably adherent to the chest wall, the diaphragm, or the pericardium by dense fibrous adhesions.

At intervals longer than four weeks the lung appeared practically the same. We obtained sections from one dog that was sacrificed four years after a subtotal pneumonectomy. The stump was 2 by 2 cm. It was covered by a tough fibrous pleural covering. The stump was airtight but air containing. It was adherent to the chest wall. A low-power microscopic view showed dimpling of the larger bronchus and distortion of the contour of the smaller bronchi. There was a large amount of fibrous tissue around the bronchus. There were some areas of normal alveolation and also areas of emphysema (Fig. 7).

These experiments prove beyond doubt that pulmonary tissue heals promptly. They also prove that lung sutures hold fast and do not tear the lung. Because of the extensive number of capillaries, the endothelial cells which play an important role in healing, the lung is better adapted to reparatory processes than many other structures in the body. The presence of smooth muscle[5] extending down to the minute ramifications of the bronchial tree and even the alveoli themselves helps to give sufficient body to the lung so that a suture may hold well and not cause a tear. On the surface of the lung the endothelium of the visceral pleura promptly comes into play to bridge any gap and produce a satisfactory apposition and a good scar. The collagenous tissue juice of the lung has a definite plastic effect. This no doubt assists in the reparatory processes present in the blood plasma and the blood cells.[6, 7]

It is obviously important not to introduce any infectious material into the wound during the suture of the lung. A mild enough pressure to overcome leakage of air and blood at the proximal portion of the lung with rubber-tipped forceps will prevent leakage of contaminated bronchial contents. *Care must be taken not to crush the lung and thus* no injury may follow. If this occurs accidentally, one may introduce compressed air at a pressure sufficient to distend the crushed elements of the lung. Healing then is prompt and no gross changes will occur.

Because of the terminal branching of the bronchovascular elements of the lung, it is very important that any excision of lung tissue must be done at right angles to the bronchovascular tree. This routine avoids injury to bronchovascular elements supplying neighboring peripheral lung segments. Thus infarction and pulmonary atelectasis do not result. If a wedge is resected it must be cut in such a way that nutrient bronchi or vessels supplying neighboring pulmonary segments are not injured. Thus atelectasis and infarction are prevented.

The lung tolerates unabsorbable sutures and little or no reaction follows. Aside from "strand formation" and diminution in the size and capacity of immediate alveoli no other reaction is noticeable. Absorbable sutures dissolve within a reasonable time and, with the aid of the macrophages, phagocytosis and solution of the suture occur.

SUMMARY

1. In the absence of infection lung tissue heals promptly and by primary intention after surgical trauma.
2. The interstitial elements of the lung are stranded together in the direction of the pull of the suture.
3. Occlusion of a stem bronchus invariably results in atelectasis of the peripheral segment of the lung.
4. Occlusion of a nutrient vessel invariably results in an infarct of the peripheral pulmonary segment.
5. Sutures of the lung do not cause tears in the organ.
6. Unabsorbable sutures remain intact and cause only a strand pattern.

7. Absorbable sutures are dissolved and absorbed leaving little or no trace of their presence.

8. A plastic tissue juice produced by the lung assists in sealing lung injuries. This juice restores the airtight and watertight function of the visceral pleura.

9. Resections of segments of the lung need not reach the root and may be made just beyond the area of pathology. The proximal segment heals promptly provided the stem bronchus and nutrient vessel are not ligated at a point that occludes air and blood supply to adjacent segments.

10. Resections of the lung at right angles to the axis of the bronchovascular elements prevent occlusion of nutrient bronchi and vessels leading to adjacent segments of the lung.

11. If a wedge is to be removed it should be pyramided. The apex of the triangle should be at the area of the root of the lung and the base at the periphery. Thus nutrient bronchi and vessels are least likely to be injured.

12. These experiments prove that it is not necessary to make root resections of lobes, lobules, or segments. Thus as much healthy lung as possible may be preserved for the future economies of the patient.

REFERENCES

1. Olch, L. Y., and Ballon, Harry C.: The Origin of Scar Tissue in Healing of the Lung, Arch. Surg. 19: 1586-1601, 1927.
2. Montgomery, G. L.: Healing of Experimental Wounds of the Lung, Brit. J. Surg. 31: 292-299, 1944.
3. Porter, C. B., Higgins, G. M., and Claggett, O. T.: The Surgical Healing of Lung Tissue; a Cytological Study, (Abstract) Bull. Am. Coll. Surgeons 32: 78, 1947.
4. Drinker, Cecil K.: Pulmonary Edema and Inflammation, Harvard University Monograph in Medicine and Public Health No. 7.
5. Macklin, Charles C.: The Musculature of the Bronchi and the Lungs, Physiol. Rev. 9: 1-60, 1929.
6. Arey, Leslie B.: Wound Healing, Physiol. Rev. 16: 327-406, 1936.
7. Robertson, H.: Phagocytosis of Foreign Material in the Lung, Physiol. Rev. 21: 112-139, 1941.
8. Graham, Evarts A., and Singer, J. J.: Successful Removal of an Entire Lung for Carcinoma of the Bronchus, J. A. M. A. 101: 1371, 1933.
   Alexander, John: Some Dramatic Thoracic Operations, J. Thoracic Surg. 5: 5, 1935.
9. Blades, Brian, and Kent, Edward M.: Individual Ligation Technique for Lower Lobe Lobectomy, J. Thoracic Surg. 10: 84-101, 1940.
10. Joannides, M.: Surgery of the Lung; Care of the Stump in Pneumonectomy and Lobectomy, Arch. Surg. 17: 91-101, 1928.
11. Overholt, R. H., and Langer, L.: New Technique for Pulmonary Segmental Resection; Its Application in Treatment of Bronchiectasis, Surg., Gynec. & Obst. 84: 257-268, 1947.
12. Joannides, M.: The Structure of the Normal Lung; Surface Stereo-microscopic Study, Arch. Int. Med. 47: 19-23, 1931.
    Joannides, M., and Olkon, D. M.: Capillary Circulation in the Alveolus Pulmonalis of the Living Dog, Arch. Int. Med. 45: 201-205, 1930.
    Olkon, D. M., and Joannides, M.: Capillaroscopic Appearance of the Pulmonary Alveoli in the Living Dog, Anat. Rec. 45: 121-127, 1930.
13. Joannides, M., and Tsoulos, G. D.: Etiology of Interstitial and Mediastinal Emphysema, Arch. Surg. 21: 333-339, 1930.
14. Joannides, M., and Steinman, F. H.: Mechanism of Pneumonia, Arch. Int. Med. 47: 24-27, 1931.
    Joannides, M.: Insufflation of Compressed Air in the Treatment of Pneumonia, Arch. Int. Med. 47: 196-201, 1931.
15. Joannides, M., and Hesse, A. L.: Pulmonary Embolism, Illinois M. J. 85: 279-286, 1944.

CHRONIC PNEUMONITIS: ITS CLINICAL AND PATHOLOGIC IMPORTANCE

REPORT OF TEN CASES SHOWING INTERSTITIAL PNEUMONITIS AND UNUSUAL CHOLESTEROL DEPOSITS

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BOSTON, MASS.

CLINICAL ASPECTS

FOR many years a clinical entity variously described as subacute, chronic interstitial, or fibrous pneumonia has been recognized.[1-9] An outstanding characteristic of the condition is its subacute or chronic clinical course. The onset may be insidious, but in the majority of cases the disease has been considered a sequela to bronchopneumonia, lobar pneumonia, persistent collapse following bronchial obstruction, or fluid accumulations. However, a definite statement concerning its origin has often not been possible. In any event, the end result is essentially the same, namely a chronic pneumonitis.

Only in recent years has surgical extirpation of inflammatory lesions of the lung provided specimens of early stages of chronic nontuberculous inflammatory disease. In the past patients afflicted with this disease either recovered or succumbed as a result of progression of the condition. The autopsy findings in such cases tend to be those of advanced stages of the lesion. During the past few years a small group of cases which conform to a fairly distinct clinical pattern and which pathologically have shown a characteristic chronic interstitial inflammatory process has been observed. The lesion in these cases was characterized by marked fibrosis and unusual deposits of cholesterol and cholesterol esters contained in large mononuclear cells. Although a similar histologic picture is sometimes seen distal to bronchial obstruction, or around chronic abscesses and severely infected bronchiectasis, these conditions have not been present in the group of cases reported here. The etiology has not yet been determined. The descriptive term "chronic pneumonitis, cholesterol type" is used to designate the condition.

The cases of ten patients with this condition who have been treated by surgical resection make up the subject of this report. In nine a lobectomy was performed. In one a pneumonectomy was required. The case histories and pathologic anatomy are presented in some detail. Some of the clinical data are summarized in Table I. Nine of the ten patients were males. The only female was a 12-year-old girl. The ages ranged up to 67 years. The disease was initiated by an acute respiratory infection in one-half the patients, and in the remainder the onset was insidious. None of these patients was under observation at the Massachusetts General Hospital during the initial stages of the disease,

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TABLE I

CASE	UNIT NUMBER	AGE (YR.)	SEX	OCCUPATION	INITIAL SYMPTOMS	CHRONIC SYMPTOMS	DURATION OF SYMPTOMS	INITIAL THERAPY	PREOPERATIVE DIAGNOSIS	BACTERIOLOGY SPUTUM	LOCATION OF LESION
1	578636 L. K.	45	M	Paper mill	Acute onset of malaise, fever, cough, and rusty sputum	Cough, sputum, hemoptysis, and chest pain	2½ mo.	Penicillin	Carcinoma	Alpha hemolytic streptococci, staphylococcus albus	Right upper lobe
2	570222 H. L. C.	33	M	Woolen mill	Sudden onset of pleuritic pain, cough, fever, and sputum	Gradually subsiding pleuritic pain, cough, and sputum	2¾ mo.	Penicillin and sulfonamide	Empyema, collapse of right middle lobe	Alpha hemolytic streptococci	Right middle lobe
3	448275 J. N.	42	M	Teacher	Acute onset of chills, fever, cough, rusty sputum, and chest pain	Occasional slight cough	4½ mo.	Sulfonamide	Carcinoma	Not done	Right upper lobe
4	474136 G. H.	56	M	Real estate	Severe upper respiratory infection and later cough, sputum, fever	Cough, sputum, fever, hemoptysis, weight loss	4½ mo.	None	Carcinoma	Alpha hemolytic streptococci, anaerobic beta hemolytic streptococci	Right middle lobe
5	557172 S. D.	32	M	Student	Upper respiratory infection with cough and greenish sputum	Chest pain, cough, mucoid sputum, intermittent fever	4¾ mo.	Penicillin	Chronic pneumonitis	Alpha hemolytic streptococci	Right middle lobe

6	26406 L. C.	32	M	Dry cleaner	Insidious onset of "pressure in chest" followed by cough, white sputum, and night sweats	Cough and sputum	9 mo.	None	Carcinoma	Not done	Left upper lobe
7	484001 M. B.	12	F	Schoolgirl	Insidious onset of cough, white sputum, and slight chest pain	Cough and sputum	11 mo.	None	Chronic pneumonitis	Hemolytic and nonhemolytic streptococci	Right middle lobe and adjacent portions of upper and lower lobes
8	479506 J. C.	67	M	Bleacher	Weight loss followed by acute onset of fever, cough, and dark sputum	Cough and sputum	12 mo.	Sulfonamide	Carcinoma	Not done	Right lower lobe
9	553055 M. H.	57	M	Accountant	Insidious onset of malaise, cough, yellow sputum, and hemoptysis	Cough and sputum	12 mo.	None	Carcinoma	Alpha hemolytic streptococci	Right upper lobe
10	189095 H. S.	36	M	Woolen mill	Recurrent attacks of pleuritic pain, cough, and yellow sputum	Cough and sputum	5 yr.	None	Bronchiectasis	Pneumococci type 29, Friedlander's bacilli, beta hemolytic streptococci	Left lower lobe

but in five of them a diagnosis of pneumonia was made by the family physician. Two patients who were said to have had pneumonia received penicillin. Two received some form of sulfonamide medication, and one received both types of medication. None was greatly improved by such treatment and the condition settled into a chronic illness in all cases. Exacerbations and remissions of acute episodes characterized the course in the majority.

The principal chronic symptoms were fever, cough, expectoration and occasional hemoptysis, pleuritic pain, and weight loss. The symptomatology was sometimes very mild and one patient had no pulmonary symptoms. The duration of symptoms varied from nine weeks to five years, but nine of the ten patients had been ill one year or less.

The findings on physical examination were usually consistent with consolidation of a portion of the lung, but signs were sometimes absent. Roentgen-ray examination of the chest was helpful in the localization of the disease. A variable portion of the lung usually showed evidence of atelectasis or consolidation, and although the appearance sometimes suggested that of an inflammatory process, the possibility of carcinoma could seldom be excluded with any degree of certainty on the basis of the roentgen-ray examination alone.

Bronchoscopic examination usually showed no abnormality or at most inflammation of the bronchial wall. Bronchograms on three patients were not helpful since the lipiodol failed to enter the bronchi in the involved segments of lung. The sputum was cultured in seven of the ten cases but no unusual organism was identified. Cytologic examinations for neoplastic cells in smears of the sputum were made in two cases. The results were negative in both. The sputum was not examined for monocytes containing doubly refractive material. This procedure might prove to be useful when performed in conjunction with a search for malignant cells in the sputum.

In six of the ten cases a preoperative diagnosis of carcinoma of the lung was made but at operation it was possible in each to recognize the inflammatory character of the disease. The density of the pleural adhesions was such as to suggest long-standing inflammation. The inflammatory masses within the parenchyma were firm and rubbery and it was not difficult to be certain that the majority of such masses were not made up of neoplastic tissue, although the possibility of similar inflammatory masses occurring behind an obstructing neoplastic bronchial lesion had to be considered. In the majority of these cases there were large, firm chronically inflamed hilar lymph nodes. In two cases a biopsy of the inflammatory mass in the lung and of the adjacent lymph nodes was performed and the failure to find neoplastic involvement indicated that what appeared at first to be a massive tumor with metastasis to the regional lymph nodes was, after all, only inflammation. Resections were then performed with more confidence that a curative procedure was being carried out.

The technical difficulties in resection of this type of disease cannot be overemphasized. In one case the individual ligation technique was impossible because of inflammation about the hilum, and a tourniquet lobectomy had to be carried out. In addition to the inflammatory reaction about the hilus, in some cases the pleural adhesions were of such dense and vascular character as to constitute a major technical difficulty. The duration of the disease had no relationship to the severity of the pleural or hilar inflammatory reaction.

The patients observed early in the series were given sulfadiazine both pre- and postoperatively and those observed later received penicillin. There were no postoperative complications. All these patients were completely relieved of their pulmonary symptoms and returned quickly to a normal state of health.

CASE REPORTS

CASE 1.—(M. G. H. No. 578636) L. K., a 45-year-old paper mill worker was in good health until nine weeks before admission to the Massachusetts General Hospital. At that time, after a three-week prodromal period of malaise, he developed an acute febrile illness characterized principally by generalized aching, fever, and nonproductive cough. He was admitted to his community hospital where he received parenteral penicillin and symptomatic treatment. While under treatment he began to raise approximately one-half cupful of brownish, occasionally bloodstreaked sputum daily. He also developed painful inspiration localized in the right upper anterior chest. Despite these changes he improved and was discharged after seven days of hospitalization. Four weeks later he was readmitted to the hospital because of persistent cough, expectoration, and chest pain. Bronchoscopy and bronchograms were reported as negative. After ten days' observation a diagnosis of carcinoma of the lung was made and he was referred to the Massachusetts General Hospital for further therapy. At that time he had lost twenty pounds in weight. Cough, expectoration, and chest pain persisted to the time of entry.

Family history was irrelevant. At the age of 7 years he had had pneumonia without known sequelae. Twenty-eight years previously he had influenza during the epidemic of 1919. Seventeen years before admission he worked for eighteen months in the digest room of a paper mill, being exposed to acid fumes. During the year preceding the present illness he had occasional sharp "pleurisy" pains in the right chest. There was no history of exposure to tuberculosis. He had not used oily nose drops.

On admission the abnormal physical findings were slight, being limited to the chest where there was increased vocal and tactile fremitus over the upper aspect of the right chest posteriorly. The temperature was normal.

Laboratory data including white blood cell count, differential leucocyte count, hemoglobin, urinalysis, serum nonprotein nitrogen, protein, chloride, cholesterol, and total fatty acids were normal. Sputum cultures grew a few alpha hemolytic streptococci and *staphylococcus albus*. No acid-fast bacilli could be found in smears of the sputum. Cytologic examination of a sputum smear for neoplastic cells was negative.

Retained lipiodol obscured details on roentgenograms made following admission. Earlier films, however, showed an area of increased density extending outward and upward from the hilum in the lower portion of the right upper lobe.

On June 25, 1947, right upper and middle lobectomies were performed. On opening the chest the lung was adherent over the lesion only. There were numerous large soft lymph nodes about the hilum. The mass in the right upper lobe was discrete and rubbery hard. There was only a partial fissure between the upper and middle lobes, and because of uncertainty as to the limits of the lesion, the middle lobe was removed also. The postoperative convalescence was uneventful. The patient was discharged eleven days following operation and has remained well during the past one and one-half years.

The pathologic diagnosis was chronic pneumonitis with an 8 mm. abscess cavity.

CASE 2.—(M. G. H. No. 570222) H. L. C. was a 33-year-old woolen mill worker. Five weeks before admission to the Massachusetts General Hospital this patient was awakened from sleep by a sharp pain in the right lower chest. This was accompanied by fever (102° to 103° F.) and cough productive of moderate amounts of brownish sputum. The pain subsided after four hours, but the cough and expectoration continued. His family physician began sulfonamide therapy. Forty-eight hours following the initial attack the patient had another bout of severe pain in the right lower chest lasting two hours. The pain was aggravated by deep breathing. Following this the pain was noticed only while the patient was coughing. After ten days the expectoration and cough diminished, but a fever ranging between 102° and 103° F. continued. Four weeks after onset he was admitted to a hospital where he received parenteral penicillin. After five days of such therapy the temperature returned to normal. On April 11, 1947, he was transferred to the Massachusetts General Hospital. By that time he had lost forty-six pounds in weight.

Systems review, past history, and family history were noncontributory. He had not been exposed to tuberculosis. He had not used oily nose drops. A tooth had been extracted under local anesthesia one month prior to the present illness, but there was no history to suggest aspiration of blood or foreign body.

Abnormal physical findings were limited to the chest. There were dullness to percussion, diminished breath sounds, and diminished tactile and vocal fremitus over the right lower chest. The diaphragm was high on the right side with limited excursion.

On admission he had an irregular fever, varying between 99° and 103° F. The blood leucocyte count was 16,000 with 85 per cent polymorphonuclears, 12 per cent lymphocytes, 2 per cent monocytes, and 1 per cent eosinophils. Other laboratory data including red blood cell count, hemoglobin, serum nonprotein nitrogen, total protein, and chloride were within normal limits. The sputum culture yielded alpha hemolytic streptococci only. Sputum smears revealed no acid-fast bacilli. Cytologic examination of sputum smears for neoplastic cells was negative.

X-ray studies showed what was thought to be a cystic or abscessed right middle lobe, pleural fluid, and partial collapse of the right upper and lower lobes.

Thoracentesis revealed thin, foul-smelling pus in the right pleural cavity. Culture yielded *Staphylococcus albus* and *Haemophilus influenzae.* On April 26, 1947, thoracotomy and drainage of a small empyema cavity were performed. During the ensuing month the patient improved rapidly. He received penicillin parenterally throughout this period. The right upper and lower lobes re-expanded, but the middle lobe remained collapsed. Bronchoscopy at this time revealed a reddened, edematous right middle lobe bronchial orifice from which came considerable thin secretion. Bronchograms revealed normal right upper lobe bronchi and moderate dilatation of the right lower lobe bronchi. No lipiodol entered the right middle lobe bronchus.

On June 2, 1947, seven weeks after entry, a right middle lobectomy was performed. The entire right pleural cavity was obliterated by thin adhesions. The visceral pleura was markedly thickened. The middle lobe was reduced in size and firm to palpation. The reaction over it was more marked than in the remaining lung. The hilum was involved in a dense inflammatory reaction of such extent that individual ligation of hilar structures was impossible. A right middle lobectomy was performed by the tourniquet technique.

The postoperative convalescence was uneventful. The patient was discharged twelve days following operation. He returned to work one month following discharge from the hospital and has remained well since.

The pathologic diagnosis was chronic pneumonitis, cholesterol type. No abscess was found.

CASE 3.—M. G. H. No. 448275) J. N., a 42-year-old man, a schoolteacher, was well until four and one-half months before the present admission, when he developed chills, fever, cough, rust-colored sputum, and pain in the right upper chest. A diagnosis of pneumococcus (type 2) pneumonia was made. He spent five weeks in another hospital and made an uneventful recovery. Sulfonamides were administered without any noticeable improvement. There was no history of his having used oily nose drops or sprays.

Following discharge he remained well except for an occasional slight cough and a rather slow return of strength. He gained ten pounds in weight. There was no fever, sputum, hemoptysis, or other evidence of continuing infection. Three weeks before admission to the

Massachusetts General Hospital his physician obtained a follow-up roentgen-ray film of the patient's chest. This showed a persistent shadow in the right upper lung field. A bronchoscopy was performed and a biopsy of suspicious looking tissue was obtained. The pathologic report was "squamous metaplasia."

At the time of admission to the Massachusetts General Hospital he had no specific complaint except what he called "nervous stomach." This had developed when he learned that he might have serious disease in his lung.

A systemic review and past history were negative except that a tonsillectomy had been performed twenty years previously with an uneventful convalescence. There was no history of exposure to tuberculosis.

Physical examination was normal except for slight dullness to percussion and tubular breathing over the right upper lung field. There were no râles.

Laboratory data including urinalysis, white and red blood cell counts, hemoglobin, serum Hinton, and nonprotein nitrogen were within normal range. Roentgen-ray films of the chest revealed partial collapse of the right upper lobe, apparently in the posterior medial segment. Within the area of collapse there appeared to be several air-containing areas such as are seen in consolidation of the lung with an open bronchus. The right lower and middle lobes showed some compensatory overexpansion. The superior mediastinal structures were retracted toward the right. There were no evident hilar glands or pleural effusion. Bronchiogenic carcinoma was considered the most likely diagnosis.

On May 19, 1944, a right upper lobectomy was performed. The lower lobe was adherent to the diaphragm but not elsewhere. The upper lobe was closely adherent to the chest wall. The density of the adhesions suggested tuberculosis. The periphery of the lobe was dissected free with some difficulty. Once this was accomplished the operation proceeded without incident. There were no enlarged lymph nodes at the hilum.

The postoperative convalescence was uneventful and the patient was discharged fourteen days after operation. He has remained in good health since.

The pathologic diagnosis was chronic pneumonitis and slight bronchiectasis.

CASE 4.—(M. G. H. No. 474130) G. H., a 56-year-old real-estate agent, was in good health until four and one-half months before admission to the Massachusetts General Hospital. At that time he developed what was believed to be a severe upper respiratory infection. Two weeks later he began to cough up a moderate amount of rust-colored, foul-smelling sputum. After two weeks this diminished and the foul odor and purulent character disappeared. He had frequent low-grade fever and night sweats. On two occasions there was streaking of blood in the sputum. He had one twelve-hour episode of right lower chest pain. He had lost fifteen pounds during the four months preceding admission. There was no history of exposure to tuberculosis. He had not used oily nose drops or sprays.

Systems review and past history were irrelevant except for the fact that he had passed dark urine during the week prior to entry.

Physical examination was entirely negative.

Laboratory data including white blood cell count, differential white blood cell count, hemoglobin, and serum Hinton were normal. Two sputum smears stained for acid-fast bacilli were negative. Urinalysis showed a few red blood cells and white blood cells per high-power field in a centrifuged specimen and 1 plus albuminuria. The sputum contained abundant alpha hemolytic streptococci and a few beta hemolytic streptococci.

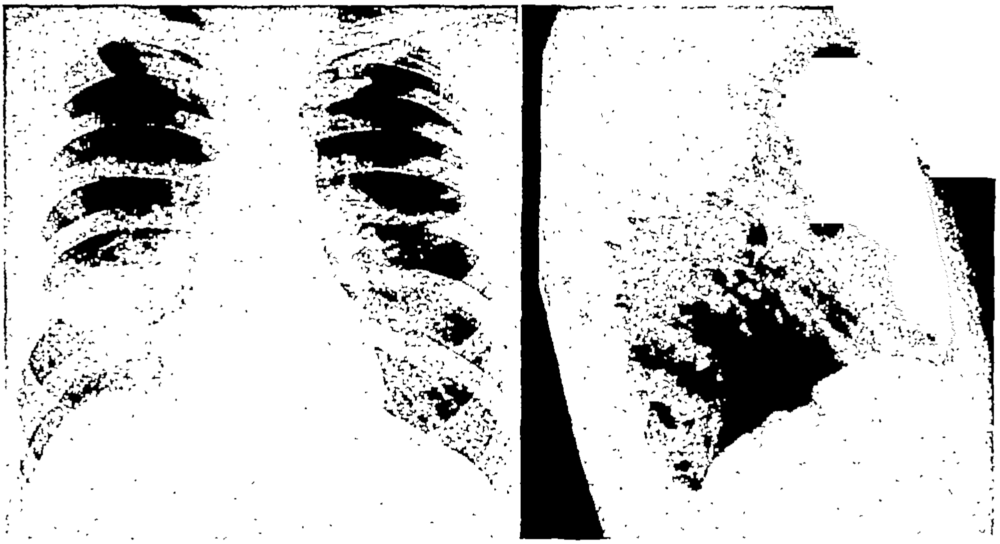
Roentgenograms of the chest (Fig. 1, *A* and *B*) revealed a sharply defined area of density in the lateral segment of the right middle lobe within which was an area of rarefaction which could have represented a small cavity. There was also a linear shadow of increased density overlying the left third interspace anteriorly and laterally. A differential diagnosis of carcinoma, abscess, septic infarct, or tuberculosis was considered. Intravenous pyelography prompted by the presence of red blood cells in the urine outlined a normal urinary tract.

Bronchoscopy revealed no abnormality.

A preoperative diagnosis of carcinoma of the lung was made and on Jan. 4, 1945, a right middle lobectomy was performed. The lobe had the gross appearance of tumor, but on palpation felt rather soft. The pleura was adherent peripherally and between the lobes. A biopsy and frozen section examination of suspicious tissue in the middle lobe revealed no evidence of malignant disease.

The postoperative convalescence was uneventful. The patient was discharged from the hospital ten days following operation. Since his discharge he has had no further pulmonary symptoms except occasional slight cough productive of a small quantity of "phlegm."

The pathologic diagnosis was acute and chronic pneumonitis.



A. B.

Fig. 1, *A* and *B* (Case 4).—Posteroanterior and right lateral roentgenograms of chest.

CASE 5.—(M. G. H. No. 557172) S. D., a 32-year-old student, was well until four and three-fourths months before admission to the Massachusetts General Hospital when he developed a respiratory infection, the most prominent feature of which was a hacking cough productive of whitish-green sputum. This continued without chills, fever, or chest pain until one month before admission. At that time he suddenly developed a sharp pain in the lower portion of the right side of the chest. The pain was so severe that he was unable to take a deep breath. A few hours later he developed a temperature of 102° F. At the same time the cough began to produce a moderate amount of rusty-brown sputum.

He was admitted to the college infirmary where, with the aid of roentgenograms of the chest, a diagnosis of pneumonia was made. He was given parenteral penicillin and became afebrile and symptom-free after four days of such therapy.

He continued to be asymptomatic except for right lower chest pain on deep inspiration until two weeks later, when he experienced a bout of coughing and raised some mucoid sputum. About the same time he developed a low-grade persistent fever. He was told that he had a collapsed right lower lobe.

Two weeks before admission to the Massachusetts General Hospital a bronchoscopy showed no abnormality except that there was white mucoid material exuding from the right lower lobe bronchus. Four days later he became more febrile and began to raise small quantities of purulent sputum. He had received penicillin through most of the illness.

Systems review, past and family history were irrelevant except that his wife had chronic pulmonary tuberculosis. Oily nose drops or spray had not been used.

Physical examination at the time of admission to the hospital was negative except for a slight decrease of expansion of the right chest, diminished breath sounds, and a prolongation of the expiratory phase of respiration over the right lower chest posteriorly.

Laboratory data including white blood cell count, differential white blood cell count, hemoglobin, total serum protein, and serum nonprotein nitrogen were normal. Urinalysis was normal except for slight albuminuria, an occasional red blood cell, and 5 white blood cells per high-power field in the sediment of a centrifuged specimen. A single sputum specimen stained for acid-fast bacilli was negative.

Roentgenograms of the chest (Fig. 2, *A* and *B*) revealed an area of increased density in the medial segment of the right middle lobe. This appeared to be against the pleura, with a rounded margin directed toward the hilus. A more linear shadow was in the apex of the right middle lobe. This extended to the periphery and had a rounded margin. There was an area of emphysema in the anterolateral portion of the right lower lobe. The remainder of this lobe was rather markedly decreased in size. There was slight shift of the mediastinum to the right. Laminagraphy of the right main bronchus showed apparent narrowing of this bronchus without definite evidence of a tumor mass. A preliminary diagnosis of chronic pneumonitis was made, but the alternative diagnosis of carcinoma was considered.

Bronchoscopy showed a slightly reddened mucosa and a small amount of gelatinous secretion coming from the right middle and lower lobe bronchi. There was no evidence of obstruction.

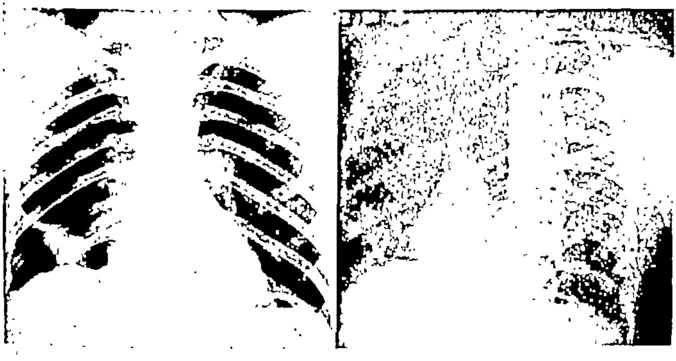

A. *B.*

Fig. 2, *A* and *B* (Case 5).—Posteroanterior and right oblique roentgenograms of chest.

On Jan. 3, 1947, a right middle lobectomy was performed. On exploration of the chest there was no fluid and no evidence of pleural reaction except between the parietal pleura and the adjacent surface of the middle lobe where the lesion lay. These adhesions were obviously inflammatory but were readily freed. The middle lobe contained a firm mass which, however, did not feel sufficiently hard to be characteristic of carcinoma. The center appeared to be somewhat soft, suggesting the presence of a cavity. A right middle lobectomy was performed. The patient's convalescence was uneventful and he was discharged fourteen days after operation. He has remained well.

The pathologic diagnosis was acute and chronic pneumonitis.

CASE 6.—(M. G. H. No. 26496) L. C., a 32-year-old man, a dry cleaner, had no complaints until nine months before admission when he developed a "pressure sensation" in the left anterior portion of the chest. He consulted his family physician who obtained roentgenograms of the chest and gave him medicine which produced some relief. Four months after the initial symptoms he developed a cough productive of small amounts of whitish sputum. At about the same time he began to have frequent night sweats. He lost ten pounds in weight. There was no fever, hemoptysis, wheezing, dyspnea, or known exposure to tuberculosis. He received no special therapy. He had not used oily nose drops or sprays.

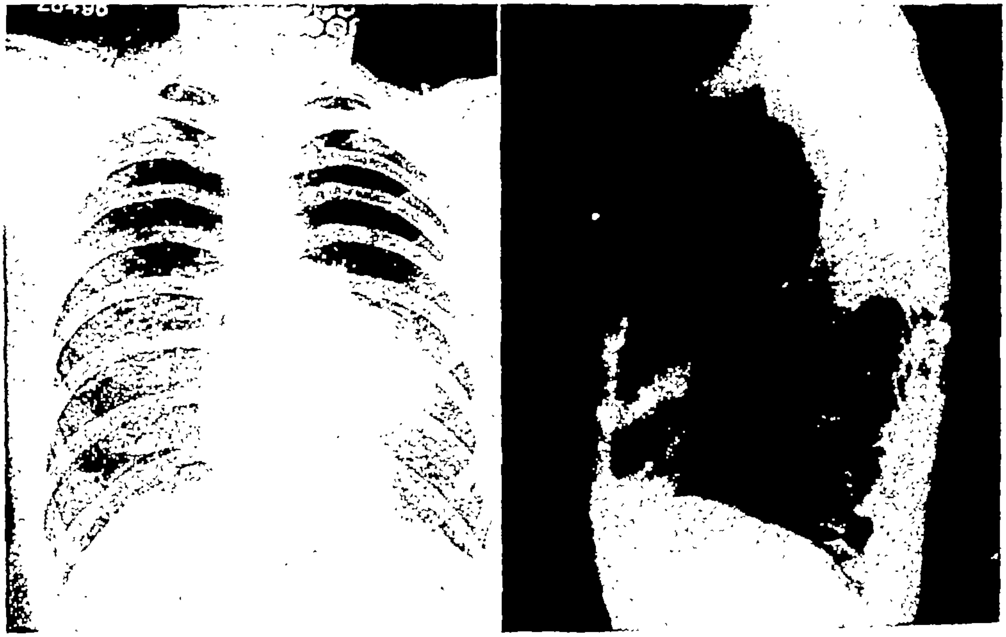
The past history and systems review were noncontributory.

Abnormal physical signs were confined to the chest where there were inspiratory râles and diminished breath sounds over the left scapular region posteriorly.

The white blood cell count was 13,100. The differential white cell and red blood cell counts and hemoglobin were normal. The red blood cells were moderately hypochromic and slightly microcytic. The platelets were increased in number. Urinalysis, serum Hinton, serum protein, and nonprotein nitrogen were normal.

Roentgenograms of the chest (Fig. 3, *A* and *B*) revealed an area of increased density extending from the left hilum downward, anteriorly and laterally in the region of the lingula. The left hilum was prominent and fluoroscopically masses were thought to be present within it. A roentgenologic diagnosis of carcinoma was made.

Bronchoscopy revealed only bronchitis on the left. No tumor was seen.



A. *B.*

Fig. 3, *A* and *B* (Case 6).—Posteroanterior and left lateral roentgenograms of chest.

On June 5, 1945, a left upper lobectomy was performed. The preoperative diagnosis was carcinoma. There were extensive adhesions between the lung and the chest wall. In the medial portion of the lingula there was an indurated mass which was densely adherent to the anterior chest wall. In the hilum of the lung there were several large soft lymph nodes. The tumor mass in the lung felt very much like carcinoma. A biopsy of the involved area, however, showed no evidence of malignant tumor. A lobectomy was performed.

The patient's convalescence was uneventful and he was discharged twelve days following operation. Recent examination revealed no evidence of abnormality and the patient has continued to work daily since his return home.

The pathologic diagnosis was acute and chronic pneumonitis.

CASE 7.—(M. G. H. No. 484001) M. B., a 12-year-old girl, was admitted to the Massachusetts General Hospital on April 5, 1945, complaining of a productive cough of eight months' duration. She was in good health until eight months before admission when she developed a cough initiated by a "tickling sensation" in the throat. This was thought to be a "summer cold." The cough soon became productive of small quantities of white mucoid sputum and shortly thereafter she began to complain of chronic fatigue. She did not gain weight at the usual rate. There were occasional brief periods of remission.

Two months before admission the cough became somewhat more severe and there were occasional paroxysms. There was no history of foreign body aspiration.

Systems review and past history were noncontributory.

Physical examination showed that the right diaphragm was elevated and moved only slightly. There were slight dullness and suppression of breath sounds over the right anterior lower chest.

The white blood cell, red blood cell, and differential counts were normal. There was 12.8 Gm. per cent of hemoglobin. Sputum and gastric washings were negative for tubercle bacilli. The sputum culture yielded abundant alpha hemolytic streptococci and occasional beta hemolytic streptococci.

Roentgenograms of the chest showed an extensive density occupying the region of the right middle and lower lobes. The right diaphragm was obliterated by the density in the right lower lung field. No diaphragmatic motion was seen fluoroscopically. The findings were considered indicative of collapse of the right lower and middle lobes.

Skin tuberculin sensitivity (O. T.) was negative in dilutions through 1:100. The blood sedimentation rate was twice the normal.

Bronchoscopy showed evidence of chronic bronchitis of the right middle and lower lobes.

On June 22, 1945, a right total pneumonectomy was performed. Preoperatively, the most likely diagnosis was believed to be chronic pneumonitis, with lung abscess as a second possibility. There were very dense and vascular pleural adhesions between the lower and middle lobes, the chest wall, the diaphragm, and the pericardium. The inflammatory process involved the entire middle lobe and the adjacent portions of the upper and lower lobes. A pneumonectomy was necessary for complete extirpation of the disease.

The postoperative convalescence was uneventful and the patient was discharged fourteen days after operation. Since operation she has had dyspnea on exertion and occasional bouts of nonproductive coughing attributed to mediastinal shift.

The pathologic diagnosis was chronic pneumonitis.

Case 8.—(M. G. H. No. 479566) J. C., a 67-year-old bleachery worker, entered the Massachusetts General Hospital on Feb. 15, 1945, with a diagnosis of carcinoma of the lung. One year before admission he began to lose weight and in the ensuing six months lost sixty pounds. Seven months before admission he had spent six weeks in his community hospital where he was treated for "virus pneumonia." Sulfonamide therapy for several weeks did not alter the course of the disease. At the end of this hospitalization he was discharged with a diagnosis of unresolved pneumonia. Following discharge he developed a cough productive of one cupful of brown, nonodorous sputum daily. However, he felt well and continued his regular work. At no time did he have chills, fever, night sweats, or hemoptysis. There was no history of exposure to tuberculosis. He had not used oily nose drops or sprays.

Systems review and past history were noncontributory.

Physical examination revealed a chronically ill man showing evidence of considerable weight loss. The tongue was smooth and red. There was moderate clubbing of the fingers. The teeth were carious. Movements of the thoracic cage were limited on the right. There was an area of dullness and suppressed breath sounds over the right mid-lung field posteriorly. There were post-tussic râles over both upper lobes.

Urinalysis was normal. The white blood cell count was 9,500. There was 11 Gm. per cent of hemoglobin. Total serum protein, serum nonprotein nitrogen, serum chloride, and prothrombin time were normal.

Roentgenogram of the chest showed decrease in the size of the right lower lobe and a homogeneous density in the dorsal division, with linear strands of increased density in the lower portion. The right hilus was somewhat enlarged and low in position. The findings were considered suggestive of carcinoma of the right lower lobe bronchus.

Bronchoscopy was entirely negative.

On March 2, 1945, a right lower lobectomy was performed. The preoperative diagnosis was carcinoma of the lung. The right lung was densely adherent everywhere, especially over the lower lobe which was shrunken and partly collapsed. There was a small empyema cavity posteriorly, fluid from which on culture yielded Friedländer's bacillus. The inflammatory nature of the process was ascertained and a right lower lobectomy was performed.

The postoperative convalescence was uneventful and the patient was discharged twelve days after operation.

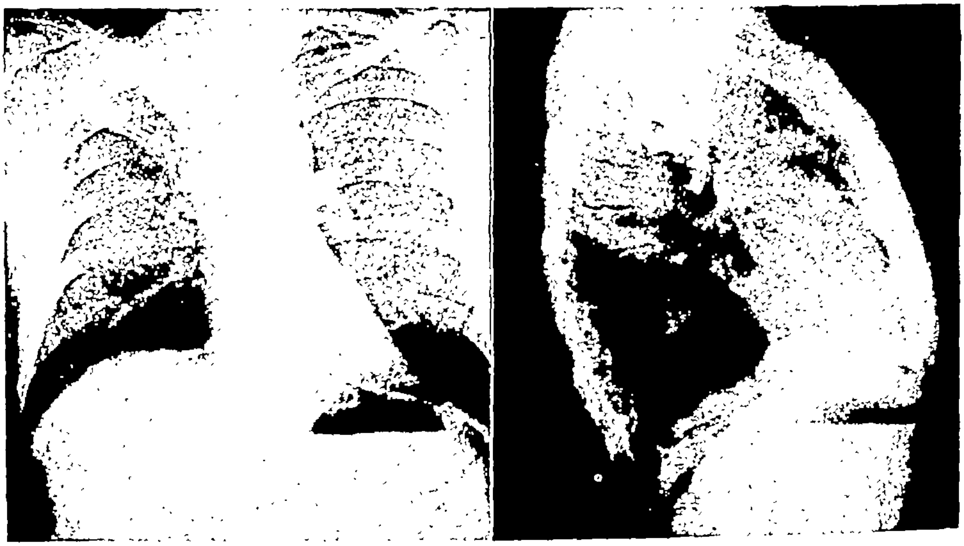
The pathologic diagnosis was chronic pneumonitis.

CASE 9.—(M. G. H. No. 553955) M. H., a 57-year-old man, an accountant, was well until one year before admission when he began to feel ''slightly under par.'' This continued and although he had no specific complaint, he was aware of a gradual decline in health.

Two months before admission to the Massachusetts General Hospital he had a brief episode of right upper chest pain associated with paroxysms of coughing productive of small amounts of yellow sputum which was occasionally malodorous. On three different occasions he raised approximately one-fourth cupful of blood. He experienced infrequent episodes of sweating. There was a low-grade fever. His appetite remained fairly good, but he lost fifteen pounds of weight during the two months before admission. He received no specific therapy. He had not used oily nose drops or sprays.

The past history and systems review were irrelevant.

At the time of entry to the hospital physical examination revealed no abnormality except for a low-grade fever and the findings in the chest. Anteriorly over the right upper chest there were hyperresonance with slightly amphoric breath sounds and increased whispered voice. Posteriorly in a localized area over the right scapula there were slight dullness to percussion, fine to medium râles, increased and harsh whispered voice sounds, amphoric breath sounds, and increased tactile fremitus.



A. *B.*

Fig. 4, *A* and *B* (Case 9).—Posteroanterior and right lateral roentgenograms of chest.

The white blood cell count on entry was 16,400, with a normal differential count. The sputum culture revealed only alpha hemolytic streptococcus. No acid-fast bacilli were found in a single smear of the sputum. The prothrombin time was twenty-one seconds as compared with a normal of fourteen seconds. Urinalysis and serum Hinton were normal.

Roentgenograms of the chest (Fig. 4, *A* and *B*) showed a hazy mottled density throughout the right upper lobe which was moderately collapsed. The right hilus was elevated and there was a suggestion of a mass in it. The lung fields were otherwise clear. The appearance was considered to be consistent with that of carcinoma of the right upper lobe.

No tumor could be visualized by bronchoscopy, but removal of a mucous plug from the right upper lobe bronchus was followed by drainage of a considerable amount of bloody pus.

While awaiting operation he was given intramuscular penicillin, which produced a prompt subsidence of the fever.

On Dec. 7, 1940, a right upper lobectomy was performed. The preoperative diagnosis was carcinoma of the lung. The upper lobe was adherent. The adhesions were of a subacute nature and could for the most part be readily separated by blunt dissection, leaving rather vascular oozing surfaces. There were enlarged lymph nodes in the hilum which were inflammatory in nature and there was nothing whatever to suggest carcinoma. It was, therefore, decided to perform a lobectomy only.

The patient's convalescence was uneventful and he was discharged thirteen days following operation. He has remained well since leaving the hospital.

The pathologic diagnosis was acute and chronic pneumonitis.

CASE 10.—(M. G. H. No. 189095) H. S., a 36-year-old man, a woolen mill worker, was well until five years before his first admission to the Massachusetts General Hospital, when he experienced the rather sudden onset of pain in the left lower chest. This persisted for a few weeks and gradually disappeared. The pain was aggravated by inspiration and he manifested a slight fever. Roentgenograms of the chest showed an area of hazy density at the base of the left lung obscuring the outline of the diaphragm and the apex of the heart. The appearance was that of an area of consolidation. He was treated for "pleurisy" by the application of a chest binder and rest.

He remained in good general health but complained of frequent "pleurisy pains" during the winter months. Two years following the initial episode he had another similar attack. Roentgenograms of the chest demonstrated a small triangular area of density at the base of the left lung. In the lateral view the costophrenic angle was obliterated by a small quantity of fluid. The findings were considered consistent with those of an infarct.

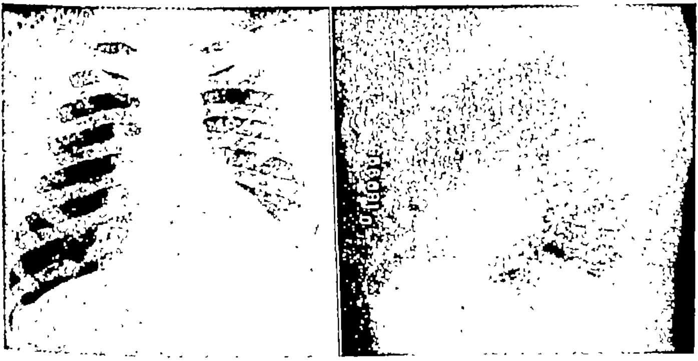

A. B.

Fig. 5, *A* and *B* (Case 10).—Posteroanterior and left lateral roentgenograms of chest.

In March, 1944, he experienced a third attack of sudden left lower chest pain which was associated with slight cough, sputum, and fever. He was admitted to the hospital for the first time.

Past history, systems review, and family history were noncontributory. There was no weight loss. He had used small quantities of oily nose spray off and on during the year preceding admission.

Physical examination was negative except for the chest. In the left lower chest laterally there were slight dullness, decreased tactile fremitus, diminished breath sounds, and abnormal vocal fremitus. On admission no râles or friction rub were heard, but later both signs were observed. The temperature on entry was 100° F.

The white blood cell count was 19,600. The sputum culture showed type 29 pneumococcus. Four sputum specimens were negative for acid-fast bacilli. Urinalysis, prothrombin time, clotting time, clot retraction, sedimentation rate, and serum Hinton were normal.

Roentgenograms of the chest (Fig. 5, *A* and *B*) demonstrated an area of increased density measuring 5 cm. in diameter occupying the left costophrenic sinus. The appearance was considered characteristic of an infarct. It was similar to that seen five years previously.

The patient was treated by bed rest and recovered in two weeks. The white blood cell count fell to 10,000 and the temperature was normal from the fourth hospital day on.

Roentgenograms of the chest taken two weeks following discharge from the hospital showed slight clearing of the process in the left lower lobe, although not enough to consider it the healing of an infarct. Lipiodol bronchograms obtained one month later revealed no positive evidence of bronchiectasis, but there was apparent obstruction of the terminal bronchi extending into the consolidated area.

The patient was readmitted to the hospital having had no further difficulty except that he had continued to raise one-fourth to one-half cupful of nonodorous yellow sputum daily. A preliminary diagnosis of bronchiectasis was made and a left lower lobectomy was performed on June 8, 1944. There were dense vascular adhesions between the lower lobe and the chest wall and especially the diaphragm. Marked inflammatory reaction and enlarged lymph nodes about the hilum complicated the dissection, but it was possible to deal with hilar structures individually in the usual manner.

The postoperative convalescence was uneventful and he was discharged thirteen days following operation. He has remained in good health since the operation.

The pathologic diagnosis was chronic pneumonitis.

DISCUSSION

Pulmonary resections for suppurative, neoplastic, and tuberculous disease have been performed with increasing frequency during recent years. There are relatively few references in the literature, however, which deal with chronic pneumonitis as a surgical problem. The most important contribution to the subject which has come to our attention is that of Freedlander and Wolpaw[3] who stressed the importance of the condition in the differential diagnosis of cases where carcinoma of the lung must be excluded. They very properly advocated early exploratory operation and the performance of a biopsy at the operating table.

Adams[9] recently reported briefly on ten cases apparently similar to ours both clinically and pathologically in which treatment was by surgery; five by lobectomy, two by pneumonectomy, two by drainage, and one in which only biopsy was done.

Thomas and Rienhoff,[10] Clagett and McDonald,[11] and Brown and Biskind[12] have each reported single cases in which resections were performed for chronic lipoid pneumonitis. Two of these cases simulated tumors and the other was associated with bronchiectasis. Clinically their cases were somewhat like ours, but aspirated oil has been excluded as an etiological agent in the present series by history and histochemical examination of the tissues.

The principal importance of chronic pneumonitis of the type described is that it may be confused with carcinoma of the lung. It has long been obvious that unless patients with pulmonary carcinoma can be operated upon in an early phase of the disease, the ultimate prognosis is dismal. In fact, if one feels obliged to wait until the diagnosis is proved by biopsy or is thoroughly obvious by roentgen-ray examination, the likelihood of effecting cures in very many cases is exceedingly slight. If progress is to be made in the management of carcinoma of the lung, therefore, an increased utilization of exploratory thoracotomy must be made in many doubtful cases.

On the other hand, at exploration the differentiation between neoplastic and chronic inflammatory disease may be difficult. Under such circumstances it is justifiable and necessary to perform frozen section biopsy examinations upon regional lymph nodes or actually upon pieces of lung removed from the suspicious area itself. This can be done with relative safety. As shown in two of the ten cases reported, this makes it possible to limit the operative procedure with more confidence to lobectomy instead of pneumonectomy. It is obvious, however, that a negative biopsy does not exclude carcinoma, for an inflammatory process similar to this may occur distal to a malignant lesion when there is bronchial obstruction. We have been unable to formulate any clear-cut criteria by which a differential diagnosis between chronic pneumonitis of the type described here and bronchiogenic carcinoma can be made preoperatively. The history combined with negative bronchoscopy and negative cytologic examination for neoplastic cells seem the most helpful factors in arriving at a correct diagnosis.

The ultimate fate of segments of the lung in which this type of chronic pneumonitis is seen remains somewhat uncertain. There is reason to believe, however, that exacerbations of acute pneumonitis, abscess formation, and ultimately the development of bronchiectasis may result. Surgical extirpation of these areas is therefore advisable when it becomes obvious that the condition has become chronic and irreversible. If a careful study of the lesion is made at the operating table, a correct diagnosis can usually be made, the proper operation performed, and the patient thus safeguarded against subsequent symptoms and disease.

PATHOLOGIC ASPECTS

In the beginning when only a few of these patients had been studied, the peculiarities of the condition under discussion were not fully appreciated. Our attention was concentrated on the eradication of presumed malignant disease of the lung, and the finding of a chronic pneumonia afforded a pleasing relief. At that time the comparatively early, more colorful phases of the process had not been encountered and the unusual features embodied in this pneumonia were not immediately apparent to us. With the acquisition of more material the changes in the pulmonary tissue could be arranged in sequence, but as no patient was subjected to operation less than two and one-half months after the onset of the pneumonia, only the late phases of the disease were observed. During this time the lung appeared to be occupied in disposing of a foreign substance, an effort repeatedly hampered by bacterial invasion. The nature but not the genesis of the foreign substance was determined during the study.

The gross and microscopic changes found in the lungs of the various patients were essentially similar, but different stages in the evolution of the process were encountered. It must be emphasized that one could not anticipate the condition of the lung from the apparent duration of the patient's illness. At times advanced pulmonary scarring had taken place a few months after the onset of definite symptoms.

The affected lobe was always decreased in volume. Fibrous adhesions of varying density were scattered over all the pleural surfaces and they were concentrated at the site of the underlying lesion, resulting in an appreciable thickening of the pleura at that point. The bronchial lymph nodes included with the specimens were several times the usual size and distinctly firmer than normal.

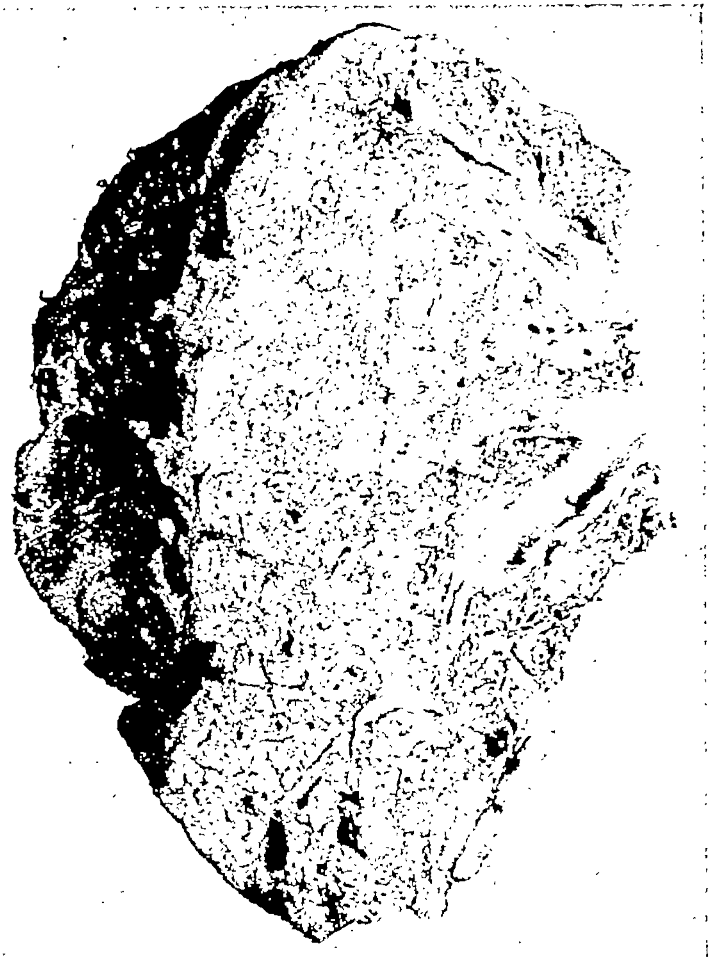


Fig. 6 (Case 2).—Complete consolidation of the middle lobe without bronchiectasis. The cut surface of the parenchyma was intensely yellow. The secondary lobules are outlined by thickened septa.

On section it was found that the pneumonic process had usually involved the entire lobe or the major portion of it. When the entire lobe was not diseased, the area of consolidation seemed to fan out from the hilum to assume a pyramidal shape with the base at the pleural surface. At least one pleural surface was always involved, and although the interlobar fissures were often obliterated by fibrous adhesions, the pneumonia had not penetrated the pleural membranes to involve an adjacent lobe except in Case 8, in which a pneumonectomy was performed. The specimen showed involvement of the entire middle lobe with extension of the process into adjacent areas of the adherent upper and lower lobes.

The cut surfaces of the lobes varied considerably in different patients. In the comparatively early stages of the process the most arresting aspect of the gross appearance was the intense yellow color of the diseased parenchyma. On closer inspection it was evident that this color was imparted by closely approximated, minute yellow dots (Fig. 6). As the pulmonary septa were thickened, glistening, and somewhat translucent, the secondary lobules of the lung were traced out in sharp definition. The primary lobules were often just discernible, indicating that the air spaces were not entirely obliterated. In the more advanced stages of the pneumonia the gross appearance was that of an increasing fibrosis of the lung. The intense yellow color had faded and was replaced by a background of gray fibrous tissue lightly flecked with golden yellow dots that were sometimes segregated in areas of varying size throughout the lobe. Localized areas of emphysema were sometimes present in the fibrosed parenchyma (Fig. 7).

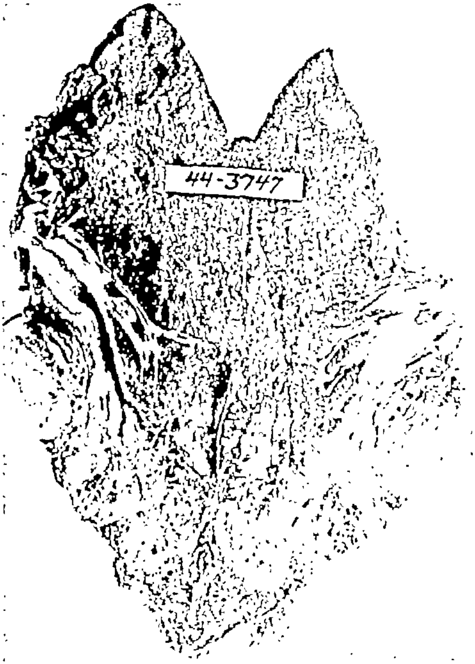


Fig. 7 (Case 10).—The lobe has been sectioned and laid open to demonstrate the late stage of the chronic pneumonitis characterized by fibrosis and patchy emphysema.

No obstructing lesion was ever found in the bronchial tree. The walls of the large bronchi were appreciably thickened and the mucosa was often red and granular, with prominent circumferential ridges; only borderline dilatation of the large bronchi was present in a small minority of the specimens. Sometimes a mucoid material was lying in the lumens. In the small bronchi with an approximate inside diameter of 1 to 2 mm. there was occasionally a marked dilatation of the lumen to 4 or 5 mm. This change was not uniform but occurred here and there throughout the area of pneumonitis and was accompanied by thinning of the bronchial wall and obvious destruction of its substance. The lumen at this point usually contained inspissated mucopurulent material. In four cases a small abscess with ragged ill-defined walls had formed in the lobe. These abscesses were never more than 1.5 cm. in diameter and they appeared to have originated from the destruction of a small bronchus and as a result of secondary infection.

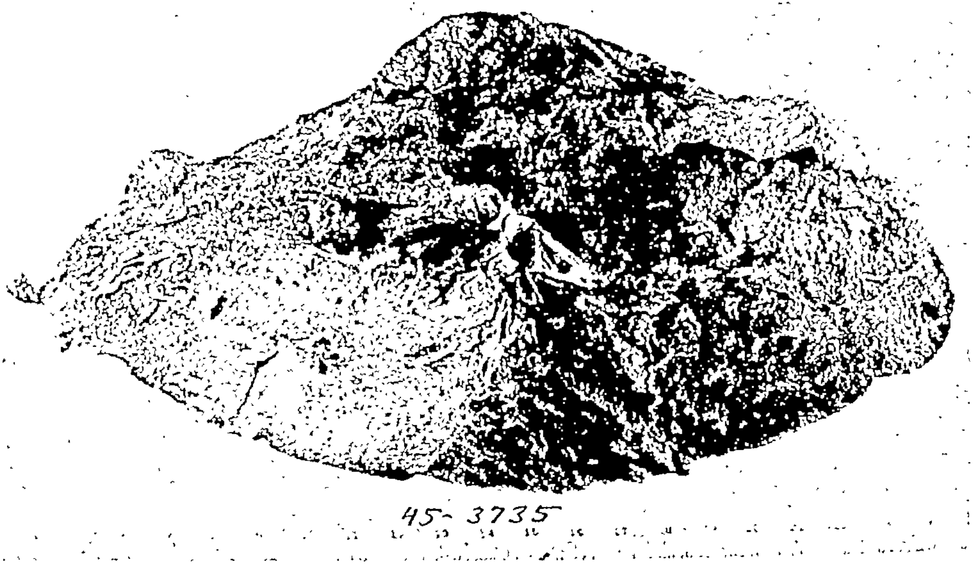


Fig. 8 (Case 8).—Hemisection of the right lower lobe showing the sharp definition of the chronic pneumonia which fans out from the hilus and involves the pleura.

The border of the pneumonia, where it did not abut the pleura, was irregular but quite clearly defined and the surrounding parenchyma was emphysematous (Fig. 8).

Microscopic examination of the ten lobes showed a chronic pneumonitis in which the end result was an extensive fibrosis of the involved segments. In many of the specimens one could trace the gamut of changes from their inception to the replacement of the functional respiratory tissues by fibrous tissue. The lobes of patients with symptoms of long duration usually showed the more advanced stages of the process, but the picture was duplicated in a few individuals who had been ill for only a few months.

The earliest change detected in the parenchyma consisted of a flooding of the primary lobules by a great number of large mononuclear cells. The cytoplasm of the majority of these cells was occupied by fine droplets so that only a mesh of lightly eosinophilic cytoplasm remained (Fig. 9). Occasionally the foamy cells assumed giant proportions and many nuclei were included in their substance (Fig. 18). Other large monocytes were not vacuolated, and of these a few contained cellular debris or a deep tan pigment, only a small portion of which gave a positive reaction for iron. The influx of these cells into the primary lobules was accompanied or followed closely by an inflammatory reaction in the interstitial tissue. The inflammatory reaction was ushered in by the appearance of edema, lymphocytes, and plasma cells in the peribronchial and perivascular tissue and, to a lesser extent, in the interlobular septa. These changes subsequently involved the alveolar walls and at this time the septal cells

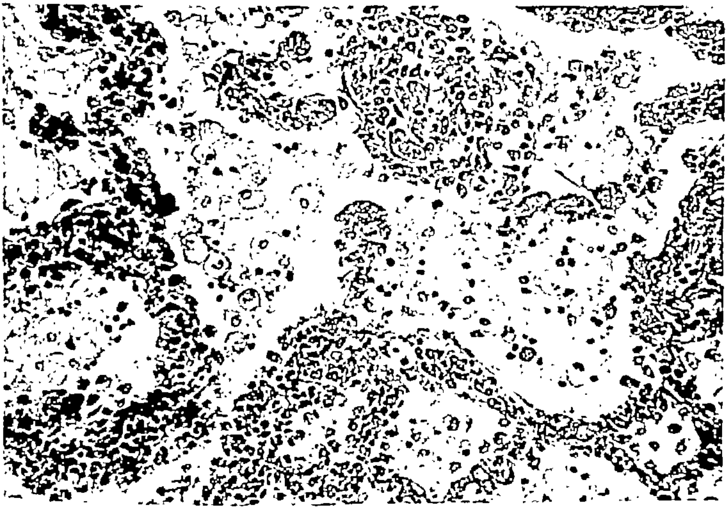


Fig. 9.—Flooding of the air spaces by vacuolated monocytes with the accompanying interstitial pneumonia.

of the alveoli had become greatly swollen and cuboidal (Fig. 10). The "epithelization" of the alveoli appeared to begin in the air sacs that abutted the interlobar septa, the pleura, and perivascular and peribronchial tissue, and gradually involved the remainder of the primary lobule. The alveolar lining cells were not vacuolated and often appeared to be desquamating into the air spaces. If they are the forerunners of the intra-alveolar foam cells, the vacuolation must take place after the cell has freed itself and is lying within the air space. The exudate within the alveoli, the alveolar ducts, and the respiratory bronchioles was now composed of large monocytes and a few lymphocytes, plasma cells, and neutrophiles; no fibrin and very little granular precipitate were present, and the neutrophiles were never vacuolated. At this juncture many aggregates of mature lymphocytes had formed in the interstitial tissues and

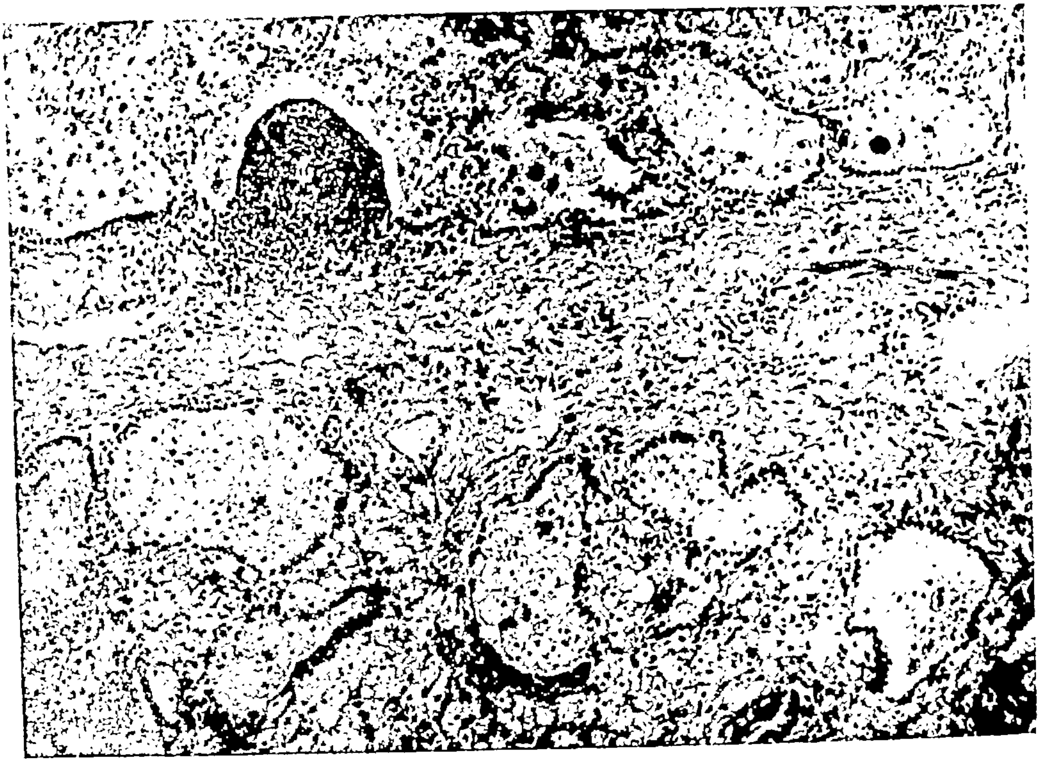


Fig. 10.—Swelling of the septal cells in the alveoli that lie against an interlobular septum.

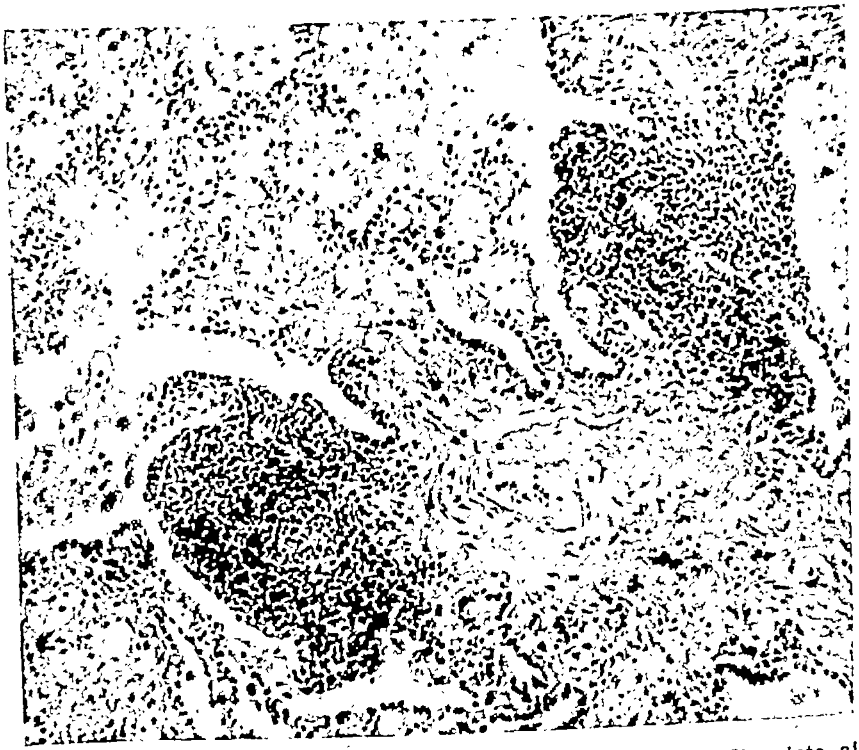


Fig. 11.—Aggregates of lymphocytes within the alveolar walls and budding into air spaces; they were covered by an unbroken line of septal cells.

budded into the air spaces, but were covered by an unbroken line of swollen septal cells (Fig. 11).

The next histologic feature of the chronic pneumonitis was the appearance and accumulation of the vacuolated macrocytes within the alveolar walls. The cells collected in such large numbers that the alveolar spaces were gradually obliterated and the primary lobules were reduced to the respiratory bronchioles and their branching alveolar ducts (Fig. 12). Occasionally large masses of foam cells obliterated the entire architecture of the lobule. In the presence of the chronic inflammatory reaction and the foam cells in the alveolar walls, a reticulum network was laid down which enclosed individual foam cells (Fig. 13). Later in the process collagen fibrils were deposited and the foam cells gradually decreased (Fig. 14). At this time vacuoles could be found in cells resembling fibroblasts. By this means the alveolar ducts *were separated by broad bands of* collagen that had replaced the foam cells, which in the beginning had obliterated the alveoli (Fig. 15). Often the alveolar ducts were isolated and choked off by the collagen (Fig. 16).

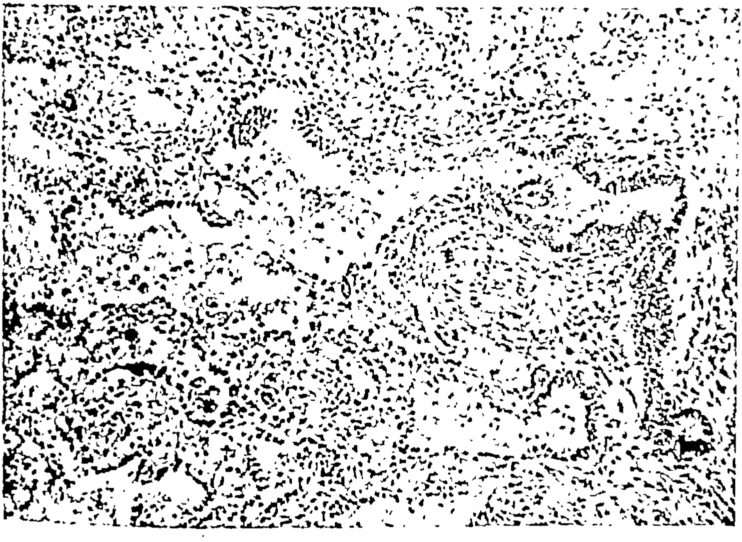


Fig. 12.—*Obliteration of the alveoli by the accumulation of vacuolated macrophages* within the alveolar walls. The respiratory bronchioles and alveolar ducts are not obliterated, but contain macrophages. A terminal bronchiole is seen on the right.

At the time when the interstitial tissue was flooded with foam cells and later when the interstitial collagen had increased, the foam cells were gradually cleared from the alveolar ducts. The obvious inference is that the foam cells migrated into the alveolar walls. However, many of them may have been cleared

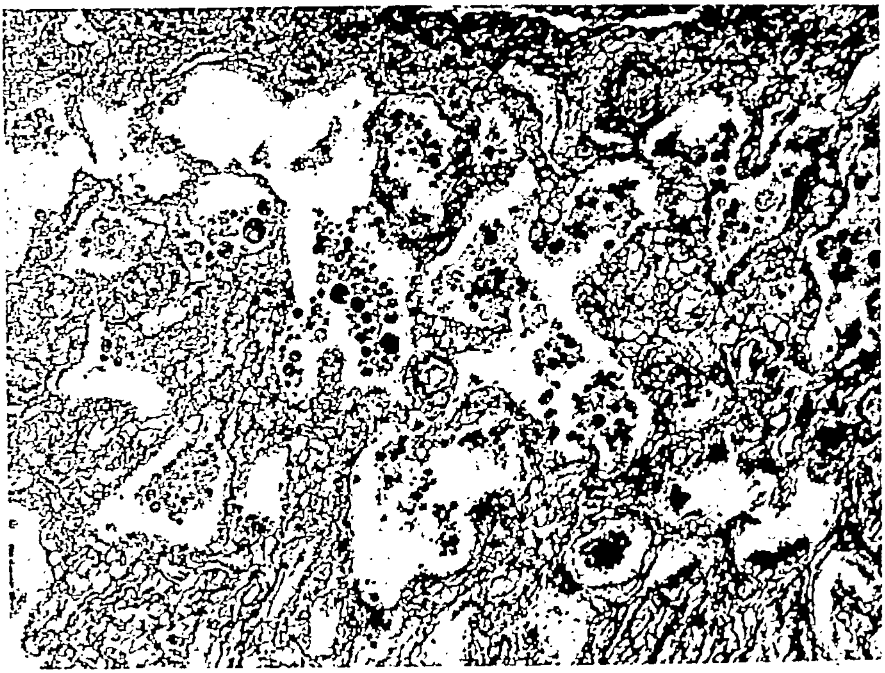


Fig. 13.—Silver impregnation to show the fine reticulum fibrils enclosing individual macrophages within the alveolar walls.

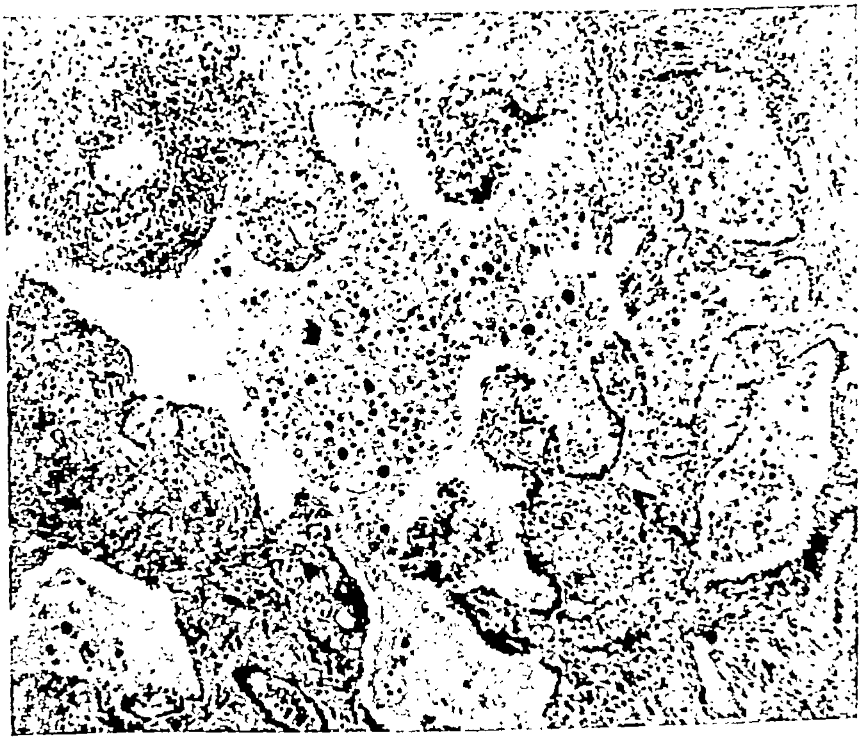


Fig. 14.—Beginning fibrosis of the alveolar walls and a decrease in vacuolated macrophages.

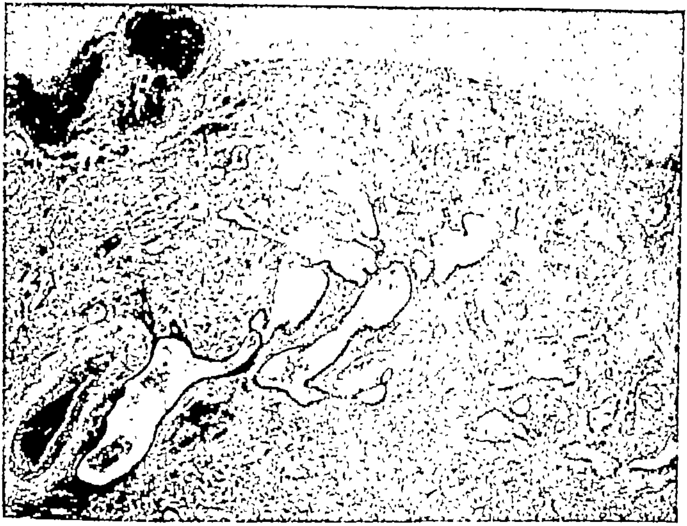


Fig. 15.—Fibrosis of a primary lobule; the dilated terminal and respiratory bronchioles and alveolar ducts still remain.

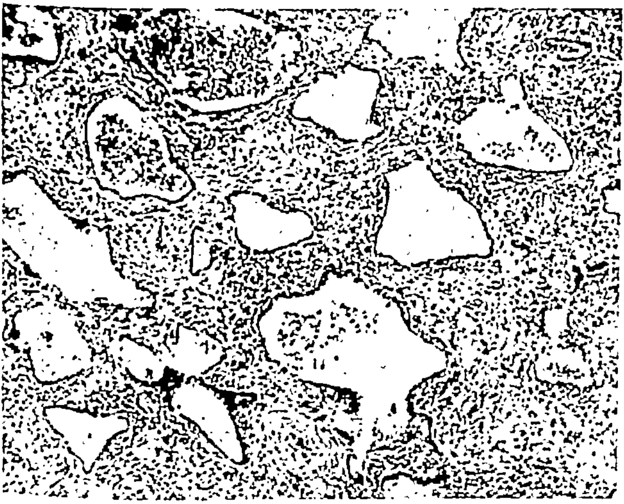


Fig. 16.—Isolation of the alveolar ducts by interstitial collagen. The ducts are lined by swollen septal cells but contain comparatively few vacuolated macrophages.

from the air spaces by incorporation in the sputum. Organization of the alveolar exudate did not take place except in the presence of what was presumably a secondary infection of the lobe. During the course of events the mild inflammatory reaction in the overlying pleura and in the interlobar septa gradually subsided, leaving these structures thickened and scarred.

The large bronchi throughout the area of pneumonitis often, but not always, showed a mild to severe infiltration by lymphocytes, plasma cells, and a few neutrophiles. Zones of squamous metaplasia and destruction of the wall were present but were not numerous and usually the epithelium was intact (Fig. 17). These changes were often present in the bronchioles, and at the end stage when fibrosis of the surrounding parenchyma had taken place, the terminations of the bronchi were greatly dilated (Fig. 15). Secondary infection of the bronchi seemed to be a fairly common event and consequently an acute purulent bronchitis was frequently superimposed upon the chronic process. In the presence of an acute reaction, necrotizing bronchiolitis was more frequent and, apparently because of this destruction, small abscesses had formed in the parenchyma of four of the specimens. Bacterial stains showed only very occasional gram-positive rods and cocci; unfortunately no cultures were taken from the lobes.

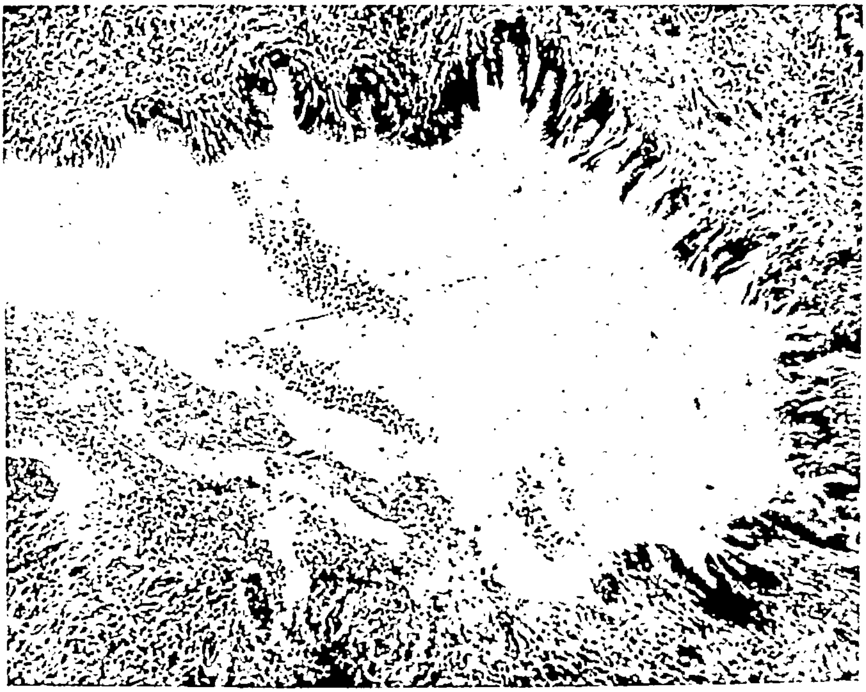


Fig. 17.—Acute and chronic bronchitis with ulceration.

The histologic changes in the lungs appeared to center around the presence of the foam-filled monocytes or, perhaps more properly, around the substance within these cells. The origin of the monocytes in the alveolar spaces and walls may or may not stem from the septal cells which formed an unbroken lining for the alveoli and alveolar ducts. In experimental pneumonias of a somewhat similar character Ross[13] believes that the intra-alveolar phagocytes originate from the connective tissue macrophages of the alveolar walls and that the cells lining the alveoli are not phagocytic. Various other opinions regarding the septal cells have been put forward by many authors.[14] In paraffin sections the substance in the monocytes was present in the form of fine vacuoles of uniform size (Fig. 18). The vacuoles filled and distended the cytoplasm of the cells and were sharply outlined by a delicate rim of lightly eosinophilic cytoplasm. The nuclei were small, deeply basophilic, and occupied the center of the cell or a somewhat eccentric position. They were never flattened against the cytoplasm membrane as in a fat cell. In brief, the monocytes were similar to xanthoma cells. The substances within the monocytes were believed to be largely cholesterol and cholesterol esters for the following reasons. The intracellular material was intensely sudanophilic and doubly refractile, and with both these technics fine crystalline needles were found to be packed within the cytoplasm. Digitonin precipitation served to emphasize these qualities and in certain areas the material no longer dissolved sudan but remained doubly refractile, which was evidence that at that point no cholesterol esters were present (Fig. 19). Generally speaking, however, cholesterol and its esters were presumably too intimately mixed to allow a differentiation between them. The Schultz reaction for cholesterol and cholesterol esters was strongly positive.

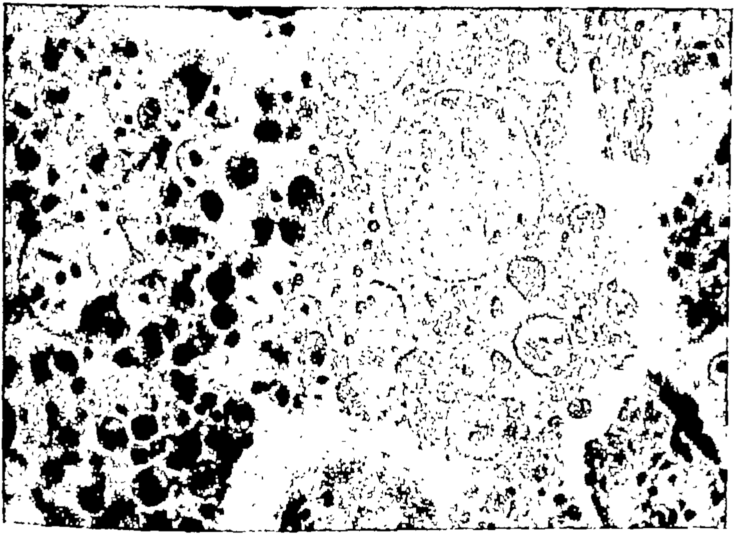


Fig. 18.—The cells of the alveolar exudate. The cytoplasmic vacuoles are finely divided and of uniform size. Several large multinucleated cells are present.

Chemical analysis of tissue taken from grossly yellow areas of lung (fixed in formalin) in Cases 4 and 10 gave extremely high values for cholesterol and cholesterol esters. In Case 10 the cholesterol was twelve times and the cholesterol ester eighteen times the normal. In Case 4 the cholesterol was twenty-nine times and the cholesterol ester ninety times the normal. Normal values expressed in milligrams per gram of wet tissue (fresh) were, cholesterol 0.3 and cholesterol ester 0.1.

The position of the extra-alveolar lipoid-containing cells is of some interest in regard to the lymphatic drainage of the lung. The cells occupied the walls of the alveoli and alveolar ducts and were soon surrounded by a network of reticulum fibrils and later by collagen fibers. Although the lymphatics of the lung are presumed to extend to the distal end of the alveolar ducts,[15] no foam cells were found in the lymphatic channels in any of the specimens. Open unobstructed lymph vessels containing a granular precipitate were identified in the bronchial walls, perivascular tissues, interlobular septa, and pleura. Furthermore, no foam cells were found in the bronchopulmonary lymph nodes, which were sometimes quite large but showed merely a nonspecific chronic lymphadenitis. Presumably, therefore, the macrophages were not removed from the lung by the lymphatic system.

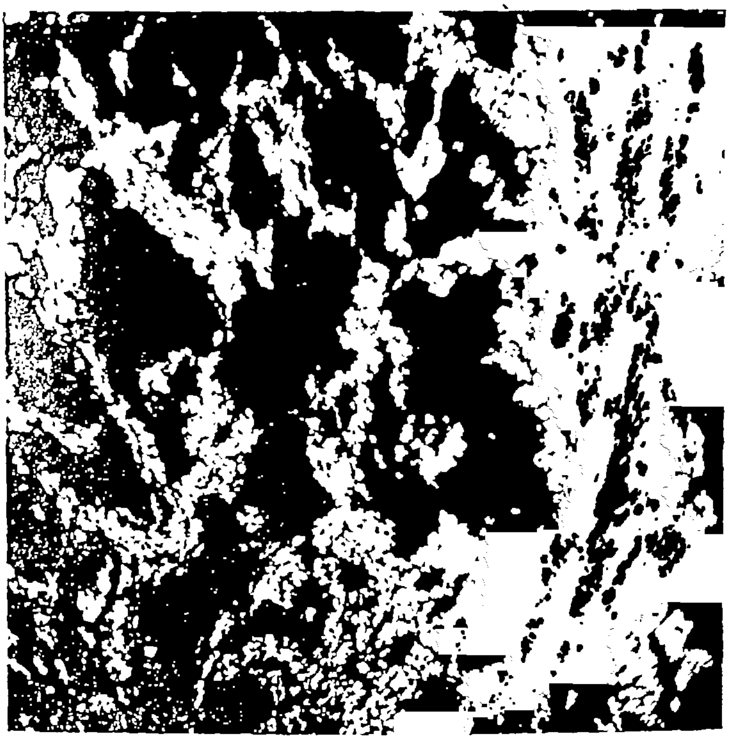


Fig 19.—Doubly refractile material outlining the alveolar walls (digitonin precipitation).

No vascular abnormalities were detected in the diseased parenchyma except in the later stages when perivascular fibrosis and endarteritic thickening became evident.

In brief, the condition under discussion is a chronic interstitial pneumonitis in association with large numbers of mononuclear cells containing cholesterol and cholesterol esters. The source of the cholesterol is not apparent. A type of pneumonia that is similar to this condition even in detail is encountered not infrequently in the presence of bronchial obstruction from whatever cause. The frequency of this parenchymal change distal to stenosing lesions of the bronchus was pointed out to us by Dr. Robert Klopstock. A biopsy and frozen section of the peripheral portion of the lobe at operation is therefore of uncertain value to the surgeon in deciding his course of action, since the microscopic changes in the lung may be the result of bronchial stenosis due to such conditions as carcinoma or bronchial adenoma. In other chronic lung diseases such as bronchiectasis, lung abscess, and tuberculosis, small areas of "cholesterol pneumonitis" are sometimes found and are easily identified in the gross by the yellow stippling of the parenchyma.

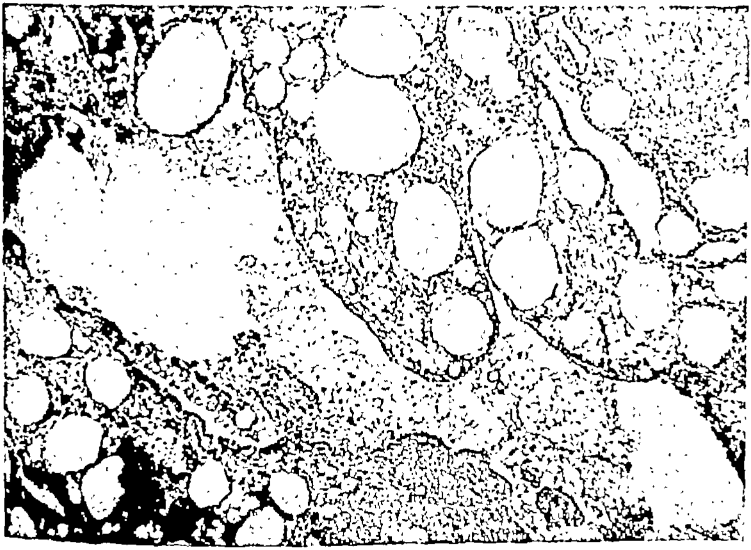


Fig. 20.—Oil aspiration pneumonia. Note the variation in size of the paraffin oil droplets and the coalescence to form large globules. The air space is an alveolar duct and the alveoli have been obliterated by the accumulation of oil-containing phagocytes within the alveolar walls. The nuclei of the phagocytes have been compressed against the cytoplasmic membrane.

The tissue changes in this lesion differ from those seen in resolving and organizing pneumonia following invasion by the pneumococcus or mixed bacteria. The mononuclear phagocytes of a resolving pneumonia often contain fine sudanophilic globules but very few of them are doubly refractile. Organization of the intra-alveolar exudate did not take place in this chronic pneumonitis in the absence of a superimposed acute pneumonitis. A striking similarity exists between the tissue reactions in cholesterol pneumonitis and in the pneumonia due to the aspiration of paraffin oil.[16-23] Freiman[24] has given us an opportunity of studying his cases of lipoid aspiration pneumonia and although the two conditions can be separated at a glance, in both, the position of the macrophages and the interstitial reaction are the same. In paraffin oil pneumonia the size of the intracellular droplets is extremely irregular due to coalescence of the globules, and the nucleus of the host cell is flattened against the cytoplasmic membrane. Furthermore, paraffin oil is not doubly refractile nor as intensely sudanophilic as cholesterol. Nevertheless, paraffin oil excites a mild interstitial reaction with the formation of lymphoid aggregates, and the vacuolated macrophages accumulate in the walls of the alveoli and alveolar ducts with gradual obliteration of these air spaces (Fig. 20). When the macrophages lie in the interstitial tissues, they are surrounded first by fine reticulum fibrils and later by collagen fibers.[22] Thus, the background of the pictures in the two pneumonias is the same, but the substances within the macrophages differ. No acid-fast membrane bordering the monocytes could be demonstrated in the various sections as in the pneumonia produced by cod-liver oil.[18, 22, 23] With one exception the patients in this group said that they had not used oily nose drops or paraffin oil.

The possibility that the condition might represent a stage in the repair of a large "incomplete" infarct of the lung in which there is extensive intra-alveolar hemorrhage and edema without necrosis of the alveolar walls[25] was considered; the breakdown of the red blood cells would be a source of cholesterol. If this were the case, one should find zones of cholesterol-laden macrocytes at the border of a "complete" infarct where the alveolar walls are intact, but the air spaces contain disintegrating red cells. With this in mind a series of pulmonary infarcts in different stages of healing were studied, but there was no similarity between the two conditions. Furthermore, clinical and experimental observations indicate that incomplete infarcts resolve in a comparatively short period without the production of a chronic pneumonitis. The injection of blood into rabbits' lungs by Strassman[26] did not produce a pneumonitis and the erythrocytes were cleared from the alveoli within a few days. Gross and microscopic examination of the lobes in our cases did not disclose vascular occlusions.

A chronic interstitial pneumonitis with large numbers of monocytes in the exudate and swelling of the septal cells is seen in such conditions as primary atypical pneumonia[27-36, 42] and the pneumonia sometimes associated with measles,[37-40] variola,[41, 42] vaccinia,[41, 42] varicella,[43] lymphocytic choriomeningitis,[42] influenza,[39, 44, 45] and whooping cough,[46, 47] as well as the psittacosis-ornithosis group,[48-52] Q fever,[53, 54] and possibly rheumatic fever,[55-59] If dilute bacterial toxins[60] or vaccine virus[61] are injected intratracheally into experimental animals, the initial acute reaction is followed in several days by an interstitial pneumonia in which the exudate is composed of lymphocytes and monocytes and is accompanied by swelling of the septal cells. McCordock and Muckenfuss[62] by the simultaneous injection of vaccine virus and bacteria into the lungs of rabbits reproduced the pulmonary changes and attendant complications seen in the pneumonia of patients who had died during the course of influenza, measles, and whooping cough. A mononuclear and septal cell response is found in the lungs of patients at autopsy and in experimental animals after roentgen radiation to the thorax.[63-65] Geever, Neubuerger, and Davis[14] in a study of pneumonias occurring in a variety of conditions encountered at autopsy did not mention intracellular cholesterol. A prominent feature in many of these pneumonias is the formation of a hyaline membrane lining the alveolar ducts.

No mention is made of intracellular cholesterol in the reports of these conditions, though occasionally "fat-laden" monocytes were seen. In MacCallum's report[44] on the pathologic anatomy of pneumonia associated with influenza, large numbers of fat-ladden monocytes were found in Cases 81, 87, and 91. These men died nineteen, eighteen, and forty-nine days, respectively, after the onset of the disease. Kay[66] studied ten lobectomy specimens from men who had developed bronchiectasis following atypical pneumonia. The lobes were resected six to thirteen *months after the attack of pneumonia and the usual changes in* bronchiectasis were found; no special features concerning the parenchymal reaction were mentioned. Intracytoplasmic and intranuclear inclusion bodies have been found in the respiratory epithelial cells in pneumonias presumed to be of viral origin.[29] Inclusion bodies were not found in the group of cases under discussion.

It is evident from this discussion that the pneumonitis which we have called colloquially "cholesterol pneumonia" has certain features in common with many other interstitial pneumonias due to a wide variety of agents, but it can be separated from these conditions by the remarkable deposition of cholesterol and cholesterol esters in the mononuclear cells of the exudate. Cholesterol pneumonia is found not uncommonly in the presence of stenosis of a major bronchus. In this group of cases bronchial stenosis could not be demonstrated by roentgenologic or bronchoscopic examinations, at operation, or after resection of the diseased lobe. It is possible that during the initial pneumonia which these patients suffered, a viscid exudate resulted in prolonged obstruction in the bronchioles thereby leading to their partial destruction and ectasia, and a chronic pneumonitis and parenchymal fibrosis of the secondary lobules beyond the obstruction. It is presumed from the evidence at hand that successive waves of secondary infection continually irritated the diseased parenchyma. Widespread necrosis of tissue or continued exudation of blood plasma into the alveoli are possible sources of the cholesterol, but tissue necrosis was not apparent in the diseased parenchyma, nor are similar changes found in chronic pulmonary edema. For the moment the origin of the cholesterol remains an intriguing mystery.

SUMMARY

Ten cases of chronic, nonsuppurative *interstitial pneumonitis treated by* surgical excision are presented in detail. The morphologic findings in the resected specimens are outlined and compared to other forms of long-standing pneumonitis, some of known etiology. *A feature of the condition is the deposit* within the pulmonary parenchyma of high concentrations of cholesterol and cholesterol esters. The origin of these materials and their bearing upon the pathogenesis of the pneumonitis are discussed.

REFERENCES

1. Scadding, J. G.: Chronic Pneumonias, Proc. Roy. Soc. Med. 31: 1259-1271, 1938.
2. Lord, F. T.: Diseases of the Bronchi, Lungs and Pleura, Philadelphia, 1925, Lea & Febiger.

3. Freedlander, S. O., and Wolpaw, S. E.: Chronic Inflammatory Lesions of the Lung Simulating Bronchogenic Carcinoma, J. THORACIC SURG. 9: 530-543, 1940.
4. Scadding, J. G.: Chronic Diffuse Broncho-pneumonia, Brit. J. Tuberc. 30: 186-204, 1936.
5. Milne, L. S.: Chronic Pneumonia (Including a Discussion of Two Cases of Syphilis of the Lung), Am. J. M. Sc. 142: 408-438, 1911.
6. Floyd, R.: Organization of Pneumonic Exudates, Am. J. M. Sc. 163: 527-548, 1922.
7. Collins, L. H., and Kornblum, K.: Chronic Pulmonary Infection Due to Friedlander Bacillus; Clinical and Roentgenologic Study, Arch. Int. Med. 43: 351-362, 1929.
8. Henke, F., and Lubarsch, O.: Handbuch der speziellen pathologischen Anatomie und Histologie, Atmungswege und Lungen, Dritter Band, Berlin, 1928, Julius Springer, pp. 1161.
9. Adams, W. E.: Chronic Nonspecific Suppurative Pneumonitis, Surgery 22: 723-724, 1947.
10. Thomas, H. M., Jr., and Rienhoff, W. F., Jr.: Lipoid Cell Pneumonia: Adult Type (Case) Simulating Lung Tumor, South. M. J. 32: 1077-1080, 1939.
11. Clagett, O. T., and McDonald, A. P.: Bronchiectasis and Lipoid Pneumonitis Associated With Large Aberrant Pulmonary Artery, Proc. Staff Meet., Mayo Clin. 20: 1-5, 1945.
12. Brown, A. L., and Biskind, G. R.: Lipoid Pneumonia, Differential Diagnosis From Pulmonary Neoplasm. Case; Treatment by Partial Lobectomy, J. A. M. A. 117: 4-6, 1941.
13. Ross, I. S.: Pulmonary Epithelium and Proliferative Reactions in the Lungs. A Study of the Cellular Response in the Lungs After Intratracheal Injection of Toxic and Non-toxic Foreign Substances, Arch. Path. 27: 478-496, 1939.
14. Geever, E. F., Neubuerger, K. T., and Davis, C. L.: The Pulmonary Alveolar Lining Under Various Pathologic Conditions in Man and Animals, Am. J. Path. 19: 913-930, 1943.
15. Miller, W. S.: The Lung, Springfield, 1937, Charles C Thomas.
16. Laughlen, G. H.: Studies on Pneumonia Following Naso-pharyngeal Injections of Oil, Am. J. Path. 1: 407-414, 1925.
17. Pinkerton, H.: Oils and Fats—Their Entrance into and Fate in the Lungs of Infants and Children, Am. J. Dis. Child. 33: 259-285, 1927.
18. Pinkerton, H.: The Reaction of Oils and Fats in the Lung, Arch. Path. 5: 380-401, 1928.
19. Ikeda, K.: Pathology of Oil Aspiration Pneumonia (Lipoid Pneumonia), Am. J. Clin. Path. 5: 89-101, 1935.
20. Ikeda, K.: Oil Aspiration Pneumonia, Am. J. Dis. Child. 49: 985-1006, 1935.
21. Ikeda, K.: Lipoid Pneumonia of the Adult Type (Paraffinoma of the Lung), Arch. Path. 23: 471-492, 1937.
22. Graef, I.: Pulmonary Changes Due to the Aspiration of Lipids and Mineral Oil, Am. J. Path. 11: 862-866, 1935.
23. Graef, I.: Studies in Lipid Pneumonia. 1. Lipid Pneumonia Due to Cod Liver Oil. 2. Lipid Pneumonia Due to Liquid Petrolatum, Arch. Path. 28: 613-667, 1939.
24. Freiman, D. G., Engelberg, H., and Merrit, W. H.: Oil Aspiration (Lipoid) Pneumonia in Adults, Arch. Int. Med. 66: 11-38, 1940.
25. Hampton, A. O., and Castleman, B.: Correlation of Postmortem Chest Teleroentgenograms With Autopsy Findings, Am. J. Roentgenol. 43: 305-325, 1940.
26. Strassman, G.: Formation of Hemosiderin in the Lungs, Arch. Path. 38: 76-81, 1944.
27. Kneeland, Y., and Smetana, H. F.: Current Bronchopneumonia of Unusual Character and Undetermined Etiology, Bull. Johns Hopkins Hosp. 67: 229-267, 1940.
28. Longcope, W. T.: Bronchopneumonia of Unknown Etiology (Variety X). Bull. Johns Hopkins Hosp. 67: 268-305, 1940.
29. Adams, J. M.: Primary Virus Pneumonitis With Cytoplasmic Inclusion Bodies, J. A. M. A. 116: 925-933, 1941.
30. Dingle, J. H., and Findland, M.: Virus Pneumonias. II. Primary Atypical Pneumonia of Unknown Etiology, New England J. Med. 227: 378-385, 1942.
31. Dingle, J. H., Aberneth, T. J., Badger, G. F., Buddingh, G. J., Fuller, A. E., Langmuir, A. D., Ruegsegger, J. M., and Wood, W. B.: Primary Atypical Pneumonia, Etiology Unknown, War Med. 3: 223-248, 1943.
32. Saphir, O.: Pathological Changes in So-called Atypical Pneumonia, Radiology 40: 339-343, 1943.
33. Campbell, T. A., Strong, P. S., Grier, G. S., and Lutz, R. J.: Primary Atypical Pneumonia, J. A. M. A. 122: 723-729, 1943.
34. Perrone, H., and Wright, M.: A Fatal Case of Atypical Pneumonia With Encephalitis, Brit. M. J. 2: 63-65, 1943.
35. Golden, A.: Pathologic Anatomy of "Atypical Pneumonia, Etiology Undetermined," Arch. Path. 38: 187-202, 1944.

36. McCoy, W. C.: Primary Atypical Pneumonia, South M. J. 39: 696-706, 1946.
37. MacCallum, W. G.: The Pathology of the Pneumonia in the U. S. Army Camps During the Winter of 1917-1918, Bull. Johns Hopkins Hosp. 20: 1-147, 1921.
38. Cole, R., and MacCallum, W. G.: Pneumonia at a Base Hospital. II. Pathology, J. A. M. A. 70: 1153-1156, 1918.
39. Opie, E. L., Blake, F. G., Small, J. C., and Rivers, T. M.: Epidemic Respiratory Disease, St. Louis, 1921, The C. V. Mosby Company.
40. Goodpasture, E. W., Auerbach, S. H., Swanson, H. S., and Cotter, E. F.: Virus Pneumonia of Infants Secondary to Epidemic Infections, Am. J. Dis. Child. 57: 997-1011, 1939.
41. Lillie, R. D.: Smallpox and Vaccinia, The Pathologic Histology, Arch. Path. 10: 241-291, 1930.
42. Reimann, H. A.: The Viral Pneumonias and Pneumonias of Probable Viral Origin, Medicine 26: 167-219, 1947.
43. Waring, J. J., Neubuerger, K. T., and Geever, E. F.: Severe Forms of Chickenpox in Adults With Autopsy Observations in a Case With Associated Pneumonia and Encephalitis, Arch. Int. Med. 69: 384-408, 1942.
44. MacCallum, W. G.: Pathological Anatomy of Pneumonia Associated With Influenza. Bull. Johns Hopkins Hosp. 20: 149-249, 1921.
45. Wolbach, S. B., and Frothingham, C.: The Influenza Epidemic at Camp Devens in 1918, Arch. Int. Med. 32: 571-600, 1923.
46. Rich, A. R.: On the Etiology and Pathogenesis of Whooping Cough, Bull. Johns Hopkins Hosp. 51: 346-360, 1936.
47. McCordock, H. A., and Smith, M. G.: Intranuclear Inclusions: Incidence and Possible Significance in Whooping Cough and in a Variety of Other Conditions, Am. J. Dis. Child. 47: 771-779, 1934.
48. Thomson, A. P., and Hiller, W. T.: Psittacosis, Lancet 1: 396-402, 1930.
49. Rivers, T. M., and Berry, G. P.: Experimentally Induced Infections in Monkeys, J. Exper. Med. 54: 129-144, 1931.
50. Rivers, T. M., Berry, G. P., and Rhoads, C. P.: Psittacosis, J. A. M. A. 95: 579-583, 1930.
51. Smadel, J. E., Wall, M. J., and Gregg, H.: An Outbreak of Psittacosis in Pigeons, Involving the Production of Inclusion Bodies and Transfer of the Disease to Man, J. Exper. Med. 78: 189-203, 1943.
52. Lillie, R. D.: The Pathology of Psittacosis in Man, Washington, D. C., 1941, National Institute of Health Bulletin 161.
53. Lillie, R. D., Perrin, T. P., and Armstrong, C.: An Institutional Outbreak of Pneumonitis III Histopathology in Man and Rhesus Monkeys in the Pneumonitis Due to Virus of "Q" Fever, Pub. Health Rep. 56: 149-155, 1941.
54. Finland, M., and Dingle, J. H.: Medical Progress; Virus Pneumonias; Pneumonias Associated With Known Non-bacterial Agents; Influenza, Psittacosis and Q Fever, New England J. Med. 227: 342-350, 1942.
55. Masson, P., Riopelle, J. L., and Martin, P.: Poumon Rheumatismal, Ann. d'anat. path. 14: 359-382, 1937.
56. Hadfield, G.: The Rheumatic Lung, Lancet 2: 710-712, 1938.
57. Epstein, E. Z., and Greenspan, E. B.: Rheumatic Pneumonia, Arch. Int. Med. 68: 1074-1094, 1941.
58. Neubuerger, K. T., Geever, E. F., and Rutledge, E. K.: Rheumatic Pneumonia, Arch. Path. 37: 1-15, 1944.
59. Seldin, D. W., Kaplan, H. S., and Bunting, H.: Rheumatic Pneumonia, Ann. Int. Med. 26: 496-520, 1947.
60. Sprunt, D. H., Martin, D. S., and Williams, G. E.: Interstitial Bronchopneumonia, J. Exper. Med. 62: 73-83, 1935.
61. Muckenfuss, R. S., McCordock, H. A., and Harter, J. S.: A Study of Vaccine Virus Pneumonia in Rabbits, Am. J. Path. 8: 63-71, 1932.
62. McCordock, H. A., and Muckenfuss, R. S.: The Similarity of Virus Pneumonia in Animals to Epidemic Influenza and Interstitial Bronchopneumonia, Am. J. Path. 9: 221-251, 1938.
63. Warren, S., and Gates, O.: Radiation Pneumonitis, Arch. Path. 30: 440-460, 1940.
64. Warren, S., and Spence, J.: Radiation Reaction in the Lung, Am. J. Roentgenol. 43: 682-701, 1940.
65. Warren, S.: Effects of Radiation on Normal Tissues, Arch. Path. 34: 917-931, 1942.
66. Kay, E. B.: Bronchiectasis Following Atypical Pneumonia, Arch. Int. Med. 75: 89-104, 1945.

PULMONARY RESECTION FOR LUNG ABSCESS

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A REVIEW of the literature which has accumulated during the past ten years concerning abscess of the lung cannot fail to impress the reader with the seriousness of the disease. Valle,[1] in reviewing results in 244 unselected cases of lung abscess treated at Barnes Hospital, St. Louis, found an over-all mortality rate of 27.4 per cent. One hundred twenty cases treated at the Massachusetts General Hospital between 1938 and 1942 were studied by Sweet.[2] Of these 18.3 per cent of the patients were found to have died. A report from Charity Hospital in New Orleans of 417 cases showed death in 49.2 per cent.[3]

The work of Neuhof[4] advocating early one-stage transthoracic drainage for acute putrid abscess, along with the development of chemotherapeutic and antibiotic agents, has greatly improved the prognosis of the patient with acute pulmonary abscess. However, the mortality figures for the chronic form of the disease remain high, and of those patients recovering many are destined to go through life as chronic pulmonary invalids. Recently Shaw and Paulson[5] and Kent and Ashburn[5] have reported series of lung abscesses in which pulmonary resection, as well as open drainage, was utilized with significant reduction in mortality and increase in cure rate.

Overholt and Rumel[6] and R. L. Moore[7] have divided lung abscesses into two groups, the simple and the complicated, depending on the pathology present. We believe this classification to be a decided improvement over the usual chronological division into "acute" and "chronic." Briefly, the simple abscess is characterized by a single cavity unassociated with extensive pneumonitis, fibrosis, or bronchiectasis. The complicated abscess, on the other hand, may have several daughter abscesses, marked pneumonitis, fibrosis, and bronchiectasis. It is apparent that while adequate drainage of a simple lung abscess may result in cure, drainage of the major focus of a complicated abscess, with healing of that abscess cavity, still leaves significant pulmonary disease present, and the patient cannot be considered well.

PREOPERATIVE STUDY

There are three examinations which should be included in the preoperative study of all patients with pulmonary abscess. Accurate x-ray localization of the abscess cavity is of prime importance, regardless of the form of surgical treatment contemplated. In addition to the usual posteroanterior roentgenogram, lateral and oblique views should be obtained. If the presence of an abscess cavity is obscured by pneumonitis or pleural fluid, the mentioned views utilizing the Bucky technique should be included.

Bronchoscopy must be carried out promptly in all patients suffering from lung abscess. Since the pathogenesis of the disease is based on bronchial ob-

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struction and impaired bronchial drainage, the importance of bronchoscopic examination in determining the presence of an endobronchial lesion is obvious. Aid in localization of the involved bronchopulmonary segment by identification of the bronchial orifice from which pus issues may be obtained, as well as possible therapeutic benefit from evacuation of some of the pus.

Bronchography constitutes the third important examination and may be conveniently conducted by introduction of the iodized oil through a catheter inserted at the time of bronchoscopy. Obstruction occurring beyond the endoscopically visible areas of the tracheobronchial tree will be noted, and the presence of complicating bronchiectasis indicated. The bronchograms are also of aid in accurate localization of the involved bronchopulmonary segments.

ANALYSIS OF CASES

During the five-year period between September, 1942, and September, 1947, thirty-eight patients received pulmonary resection for lung abscess at Fitzsimons General Hospital. These patients were treated since the advent of the sulfonamide drugs, and after 1943 most of them also received penicillin. In all of the patients an attempt was made to utilize the individual ligation technique in the management of the hilar structures. In two instances this was found to be technically impossible and tourniquet resection was performed. Table I shows the anatomical location of the lesions treated.

TABLE I. LOCATION OF LUNG ABSCESS

Left upper lobe	9	Right upper lobe	9
Lingula	0	Right middle lobe	2
Left lower lobe	10	Right lower lobe	8

The equal frequency of upper and lower lobe lesions in the series, in spite of the more common occurrence of abscess in the lower lobes, may be explained by our willingness to resect upper lobe lesions whether simple or complicated.

In attempting to determine the etiology of the abscess in the cases reported, pneumonia was found to be the most frequent underlying lesion. Since the earliest x-ray manifestation of lung abscess is an area of pneumonitis, the significance of the postpneumonic group is questionable. Table II lists the etiology of the cases in this series as could best be determined.

TABLE II. ETIOLOGY OF LUNG ABSCESS

Postpneumonic	11
Trauma	5
Followed upper respiratory infection	4
Postoperative	3
Infected bronchogenic cyst	2
Vincent's angina	1
Pre-existent bronchiectasis	1
Amebic abscess of liver	1
Undetermined	10

Thirty-six of the thirty-eight patients had complicated lung abscesses. In many, of course, several complicating lesions were present. Bronchiectasis was the most frequent complicating factor, being present twenty times. Multiple abscess formation, extensive pneumonitis, and extensive fibrosis were also commonly noted.

TABLE III. COMPLICATING FACTORS

Bronchiectasis	20
Multiple abscesses	12
Extensive pneumonitis	11
Extensive pulmonary fibrosis	9
Bronchopleural fistula	3
Foreign body	2
Bronchoesophageal fistula	1
Sinus tract from liver	1
Empyema	1

Inquiry into the duration of symptoms prior to operation disclosed a range of from seven weeks to eleven years. The average duration prior to operation was one year.

TREATMENT

After the diagnosis of complicated lung abscess has been made and the diseased area adequately mapped, the problem of treatment presents itself. We feel that pulmonary resection is the treatment of choice. Ideally, this may be accomplished as the primary surgical procedure. However, if the patient remains toxic in spite of adequate antibiotic and chemotherapy and is felt to be a poor risk for extensive surgery, preliminary drainage of the mother abscess should be performed, with later resection when the patient is in better condition to withstand operation.

The management of upper lobe abscess presents a special problem, due to the inadequacy of bronchoscopic visualization of this area. A recent survey in this hospital showed that in less than 50 per cent of the cases of bronchogenic carcinoma was the primary lesion in a bronchoscopically visible portion of the bronchial tree.[8] This is of particular significance when one considers that various studies have shown that from 12 to 48 per cent of lung carcinoma shows evidence of cavitation.[9-12] Therefore, since bronchoscopic examination of the upper lobe bronchi is decidedly limited, we believe that lung abscesses occurring in the upper lobes should be treated by pulmonary resection, regardless of whether or not complicating factors can be demonstrated preoperatively. This is of particular importance in the management of patients in the middle and older age groups.

Of the thirty-eight patients in this series receiving pulmonary resection, five had had previous open drainage. Single lobe lobectomy was performed twenty-nine times, while in two patients two lobes were removed. In three cases the lesions were sufficiently localized to be removed by segmental resection. Total pneumonectomy was necessary in four patients.

The postoperative complications which were seen are listed in Table IV. Empyema occurred in five patients or 13.2 per cent of the total group. This is approximately three times as frequent as in our series of lobectomy for bron-

TABLE IV. POSTOPERATIVE COMPLICATIONS

Empyema	5
Postoperative pneumonitis	1
Drainage from site of previous open drainage	1
Transient pulmonary edema	1

chiectasis and may be attributed to increased difficulty of resection in abscess cases as well as to the disease itself.

There were three deaths in this series, a fatality rate of 7.9 per cent. Two of the three deaths occurred in patients undergoing pneumonectomy, one dying from pulmonary edema and acute cor pulmonale, and one from hemorrhage from the stump of the left pulmonary artery. The third death occurred on the eleventh postoperative day following lobectomy and was due to multiple brain abscesses and meningitis.

SUMMARY AND CONCLUSIONS

1. The preoperative examination of all patients with lung abscess should include accurate x-ray localization of the lesion, bronchoscopy, and bronchography.
2. Pulmonary resection is the treatment of choice in cases of complicated lung abscess and in lung abscesses located in the upper lobes.
3. A series of thirty-eight lung abscesses has been subjected to this management during the past five years, with a mortality rate of less than 8 per cent.

REFERENCES

1. Valle, A. R.: Lung Abscess: An Analysis of 244 Cases, Surg., Gynec. & Obst. 81: 278, 1945.
2. Sweet, Richard H.: An Analysis of the Massachusetts General Hospital Cases of Lung Abscess from 1938 through 1942, Surg., Gynec., & Obst. 80: 568-574, 1945.
3. D'Ingianni, Vincente: Non-tuberculous Lung Abscesses: Survey of Four Hundred Seventeen Cases, Am. J. Surg. 65: 46-55, 1944.
4. Neuhof, Harold: Acute Putrid Abscess of the Lung: Surg., Gynec., & Obst. 80: 351-354, 1945.
5. Quoted by Meade; Richard H. Jr., The American Association for Thoracic Surgery: A Report of Its Meeting on May 28, 29 and 30, 1947, Am. Rev. Tuberc. 57: 18-24, 1948.
6. Overholt, Richard H., and Rumel, William R.: Factors in the Reduction of Mortality from Pulmonary Abscess, New England J. Med. 224: 440-454, 1941.
7. Moore, Richmond L.: Pulmonary Abscess: A Surgical Problem, Ann. Surg. 116: 373-386, 1942.
8. Grow, John B., Bradford, M. L., and Mahon, Hugh W.: Exploratory Thoracotomy in the Management of Intrathoracic Disease. To be published.
9. Rosedale, M., and McKay, D. R.: A Study of 47 Cases of Bronchogenic Carcinoma Am. J. Cancer 26: 493-500, 1936.
10. Jaffe, R. H.: The Primary Carcinoma of the Lung: A Review of 100 Autopsies J. Lab. & Clin. Med. 20: 1227-1237, 1935.
11. Fishberg, M., and Rubin, E. H.: Carcinomatous Abscess of the Lung, Am. J. M. Sc. 178: 20-29, 1929.
12. Kolotsky, S.: Primary Carcinoma of the Lung: A Clinical and Pathologic Study of 100 Cases, Arch. Int. Med. 62: 636-651, 1938.

Erratum

Concerning the article by J. R. McDonald, S. W. Harrington, and O. T. Clagett, on Obstructive Pneumonitis of Neoplastic Origin, in the February, 1949, issue of the JOURNAL, pp. 97-112, the authors wish it to be known that they intended to supply the name of Dr. Donald S. Morris on the manuscript or galley proof before the paper was published. They greatly regret that, by oversight, they failed in their intention.

A NEW FLEXIBLE DOUBLE-LUMEN CATHETER FOR BRONCHOSPIROMETRY

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THE first determinations of separate lung function in human subjects were made by Jacobaeus, Frenckner, and Björkman[1] in 1932. The apparatus used was a rigid double-lumen bronchoscope, introduced under direct vision and so positioned that air exchange to the two lungs was maintained through the respective channels of the bronchoscope; ventilation and oxygen absorption of the two lungs were recorded simultaneously. In 1934 Frenckner[2] greatly simplified the technic by altering and improving the double bronchoscope.

In 1936, Bezançon and his associates[3] made a number of observations, using a single-lumen bronchoscope, recording data first from one lung and then from the other. A great deal of technical difficulties arose in introducing these rigid bronchoscopes into the desired position. Also, the procedure was often very disagreeable to the patient.

In 1939, Gebauer[4] described a flexible soft-rubber double-lumen catheter, constructed for use in bronchospirometry. Independently of him Zavod[5] in 1940 described a similar catheter. These catheters simplify in some ways the procedure and make the examination less disagreeable to the patient. There is a flexible steel plate in the tip of the catheter and the capillary air leads are radiopaque. By means of fluoroscopy the catheter is placed in the correct position. In cases with marked distortion of the upper part of the trachea to the left, there are often difficulties in introducing the catheter into the left main bronchus. The usefulness of this type of double-lumen catheter is also limited by the small size of the breathing channels which it provides, and the increased respiratory effort entailed in "stenosis breathing" may amount to moderate or severe dyspnea sufficient to interfere with completion of the test. Furthermore, it is believed that in cases with marked disproportion between the ventilation of the two lungs, air exchange to the good lung is more restricted than that to the poor one. If this is true, the determination of the relative ventilation of the two lungs will be inaccurate. In patients with large amounts of viscous sputum it is often impossible to obtain satisfactory records because of obstruction of the channels.

To avoid this stenosis breathing Norris, Long, Oppenheimer, and Wester[6] in 1948 described a single-lumen catheter for use in simultaneous determination of separate lung function. The lumen of the catheter provides an airway to the left lung, and air exchange to the right lung is maintained around the catheter and through the larynx. The catheters (22-26 French), which have

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The catheter described in this paper was kindly made by Trelleborgs Gummifabrik, Trelleborg, Sweden.

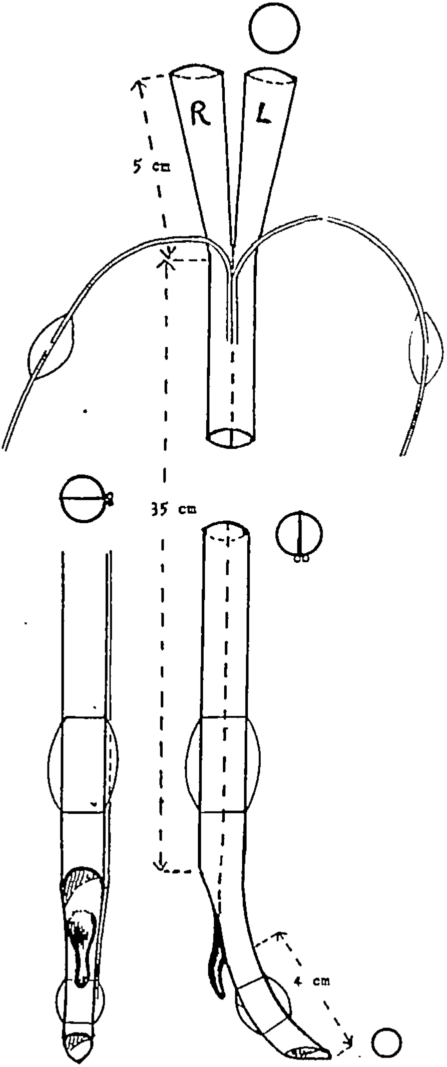

Fig. 1.—A flexible double-lumen catheter for bronchospirometry made in two sizes. The cross section is on the left side in the bronchial part circular and in the tracheal part semicircular. The area is the same in both (about 39 square mm. in the large size and 25 square mm. in the small size). The outer diameter is 13-14 mm. in the large size and 11-12 mm. in the small one.

an inflatable cuff, are of metal spiral construction and sheathed in latex Penrose tubing. The catheter is introduced on a curved stylet under mirror guidance and advanced into the left bronchus under fluoroscopic control. The outer end of the catheter is then brought through a Connell mask and through a rubber diaphragm in one arm of a Heidenbrinck Y-connector. The largest size of this catheter (inside diameter 7 mm.) offers a calculated resistance to air flow, which is approximately one fifth of that offered by one channel of the largest size of Zavod's double-lumen catheter.

I am convinced that the introduction of this method is of great value in bronchospirometry. Sometimes, however, there is, under the fluoroscope, difficulty in determining if the inflatable cuff is placed just between the carina and the mouth of the left upper lobe bronchus. In order to avoid this difficulty and to obviate the time-consuming procedure of fluoroscopy, we have constructed a flexible double-lumen rubber catheter of approximately the same rigidity as an ordinary urethral catheter. It is provided with a little hook that is automatically engaged by the carina. Fig. 1 illustrates the construction. The lumen of each channel in the largest model (that is, the one used in male adults) is the same size as the single-lumen catheter of Norris and associates. For women we use a somewhat smaller size with a diameter in each channel of 6 mm.

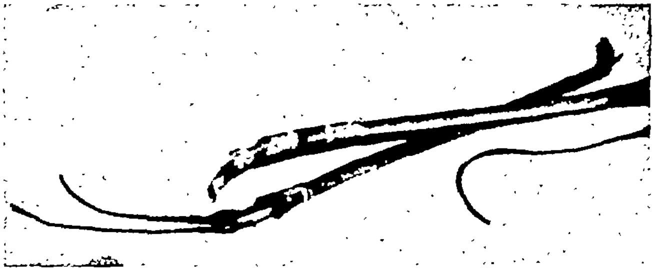

Fig. 2.—Photograph of the catheter manufactured in two sizes.

The Use of the Catheter.—Before the examination a curved metal stylet is introduced into the bronchial channel of the catheter. The rubber hook is tied down to the catheter with a silk thread in order to facilitate the introduction through the larynx. The knot is tied in such a way that it is easy to open when pulling on one end of the thread. The catheter is then introduced under mirror guidance. When the hook has passed the vocal cords, the stylet is removed and the knot is untied by means of a slight tug on the thread, which is then pulled out completely. The catheter is now turned 90 degrees to the left and it is gently pushed downward until the hook is engaged by the carina. It is very easy to feel when the catheter is in correct position. The cuffs are inflated with a syringe until the control bags on the upper part of the capillary air leads are distended. The capillary air leads are then clamped off. By observing the tension in the control bags, it has been easy to obtain the required distension in the cuffs. This has obviated the necessity for manometric control of the pressure in the cuffs. The breathing channels are then connected with the twinspirometer and the examination may commence.

The catheter is constructed of rubber of moderate rigidity which makes it easy to handle. When it is being pushed down through the trachea, the bronchial end of the catheter exerts a slight elastic pressure on the left wall. It therefore automatically enters the left main bronchus even in those pathological states where the angle between the latter and the trachea approaches 90 degrees. The pressure exerted, however, is not so great as to traumatize the mucus membrane.

Premedication and topical anesthesia are approximately those employed for bronchoscopy. It is of great importance to give only a small dose of morphine in order not to depress the activity of the respiratory center. Otherwise, respiration becomes irregular and difficulties are encountered in measuring the oxygen consumption. For topical anesthesia the pharynx is sprayed lightly several times with a 2 per cent solution of pantocaine. The larynx, trachea, and larger bronchi are then anesthetized by fractional instillation of about 2 ml. of the same solution.

Employing this type of catheter, we have, during the last year, done over 60 bronchospirometric examinations and in no case has there been any difficulty in introducing it into the correct position. Nor have we seen any untoward effect from the procedure. After premedication with atropine or scopyl (metylscopolamine) we have never seen any obstruction by secretion, although in some instances we have continued the examination for as long as one hour. We have also been able to show that this catheter exerts almost no influence whatever on the respiratory movements. The summation of the vital capacities from both lungs has never by earlier methods with double catheters given the same result as obtained by ordinary spirometry. Especially with the rigid double bronchoscope the patients did not expire freely and there was a large amount of reserve air. With the flexible catheter of Zavod's type, a closer correlation was achieved but according to Pinner[7] it was necessary in the usual spirometric test to add a "stenosis" of the same magnitude as that produced by the introduction of the bronchial catheter in order to obtain a close correlation. Measured by our double-lumen catheter there is a very close correlation between the sum of the vital capacities from both lungs and

TABLE I. A COMPARISON OF THE SUMMATION OF THE VITAL CAPACITIES FROM BOTH LUNGS MEASURED BY OUR DOUBLE-LUMEN CATHETER AND THE VITAL CAPACITY OBTAINED BY ORDINARY SPIROMETRY IN SEVEN CONSECUTIVE CASES

PATIENT	VITAL CAPACITY			VITAL CAPACITY OBTAINED BY ORDINARY SPIROMETRY
	RIGHT LUNG	LEFT LUNG	RIGHT + LEFT LUNG	
H. S.	1780	380	2160	2010
F. V.	1250	390	1640	1720
G. H.	2780	2360	5140	5130
K. A.	1120	450	1570	1490
E. J.	1280	500	1780	1910
J. L.	490	920	1410	1500
A. G.	440	670	1110	1190

the result obtained from ordinary spirometry without any introduced stenosis. (See Table I). To get the conditions as similar as possible we have done the ordinary spirometry about a quarter of an hour after the bronchospirometric test before the anesthesia has disappeared.

We have also found that the lumina of the channels are large enough to permit bronchospirometric examinations on patients exercising on a cycle ergometer. This can be of great value in some cases in order to study the reserve capacity of oxygen absorption in an affected lung. These investigations are being continued and will be dealt with in a further publication.

REFERENCES

1. Jacobaeus, H. C., Frenckner, P., and Björkman, S.: Some Attempts at Determining the Volume and Function of Each Lung Separately, Acta Med. Scandinav. 79: 174, 1932.
2. Frenckner, P.: Bronchial and Tracheal Catheterization. Acta Oto-larynx. Suppl. XX, 1934.
3. Bezançon, F., Braun, P., Soulas, G., and Cachin, M.: La Division des Airs, Examen Functionelle des Poumons Separés. Bull. Acad. de méd., Paris 115: 12, 1936.
4. Gebauer, P. W.: A Catheter for Bronchospirometry. J. THORACIC SURG. 8: 674, 1939.
5. Zavod, W. A.: Bronchospirography: Description of Catheter and Technique of Intubation, J. THORACIC SURG. 10: 27, 1940.
6. Norris, C. M., Long, J., Oppenheimer, M. J., and Wester, M. R.. Bronchospirography, Apparatus and Technique, J. THORACIC SURG. 17: 357, 1948.
7. Pinner, M.: Discussion on Bronchospirography, J. THORACIC SURG. 10: 42, 1940.

NOTICE

The Chairman of the Membership Committee of the American Association for Thoracic Surgery wishes to announce that applications for both associate and active membership must be received by him before Jan. 1, 1950. Applications received after this date will not be considered before the next meeting of the Association. All applications should be submitted to Dr. B. N. Carter, Cincinnati General Hospital, Cincinnati, Ohio.

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Original Communications

CHRONIC ATELECTASIS AND PNEUMONITIS OF THE MIDDLE LOBE

DONALD L. PAULSON, M.D., AND ROBERT R. SHAW, M.D., DALLAS, TEXAS

ONE of us (D.L.P.), in 1945, became interested in chronic atelectasis and pneumonitis of the middle lobe of the right lung. Several patients were seen who had an obstruction of the bronchus of the middle lobe secondary to extrinsic pressure by calcified lymph nodes and resulting in atelectasis and pneumonitis of the middle lobe. Subsequently other patients were operated upon who had the same condition with the exception that instead of calcified lymph nodes the bronchus of the middle lobe was surrounded by large inflamed lymph nodes. In the last three years a total of thirty-two patients having chronic atelectasis and pneumonitis of the right middle lobe for periods varying from five months to twenty years has been seen. Twenty-nine of these thirty-two patients have been operated upon and a right middle lobectomy performed. A review of the symptomatology and the findings by roentgenography, bronchoscopy, and bronchography reveals a characteristic diagnostic pattern on the basis of which the diagnosis can be made preoperatively with a high degree of accuracy. In our opinion the frequency and characteristic pattern of this type of pulmonary suppurative disease justifies its separation as a clinical entity and stimulated our making this report.

PATHOLOGY

The essential pathologic feature of this condition consists of bronchial obstruction of the middle lobe bronchus with resulting atelectasis, pneumonitis, and fibrosis of the middle lobe. The bronchial wall has been found to be involved with inflammation and edema in most cases (Fig. 1). Enlarged peribronchial lymph nodes about the right middle lobe bronchus have been found in fifteen patients. These inflamed lymph nodes are large indurated nodes which in some instances completely surround the bronchus of the middle lobe at its origin from the intermediary bronchus. It is conceivable that these nodes which are probably secondary to inflammation within the right middle lobe produce pressure on the bronchus, thus increasing the obstruction of an already

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Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

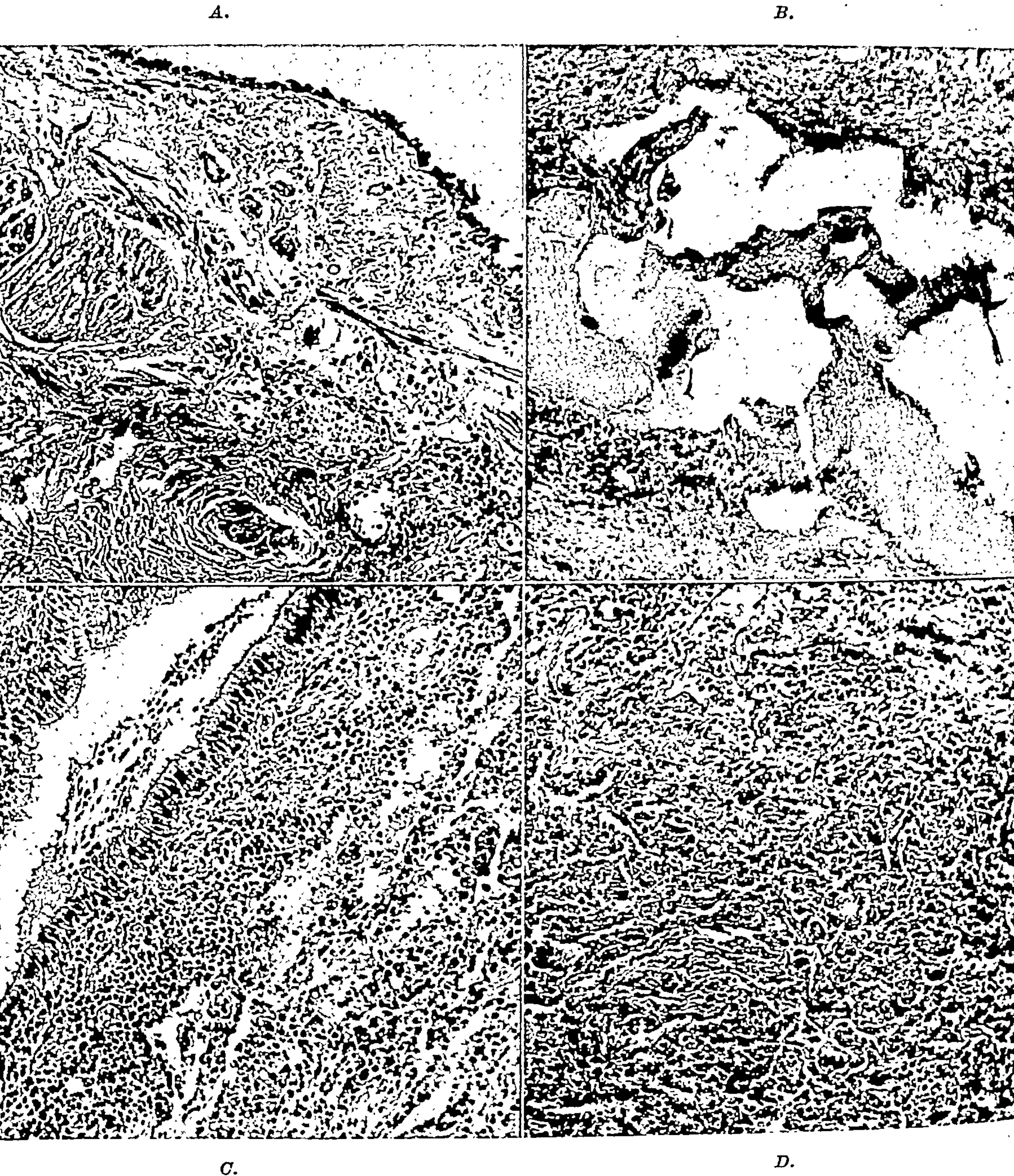


Fig. 1.—Photomicrographs (×100) of sections from the middle lobe of various patients having chronic atelectasis and pneumonitis of this lobe, illustrating: *A*, edema and inflammation in the wall of a large bronchus; *B*, a bronchus at the site of erosion by a calcified mass. Masses of hyalinized and calcified material are embedded in dense fibrous tissue which has replaced the mucosa of this bronchus. Chronic inflammatory cells of the lymphocytic type can be seen scattered throughout the connective tissue. Ulceration of the bronchial mucosa is evident, and in the vicinity of the bronchus. marked pulmonary fibrosis and chronic pneumonitis are noted. *C*, Section from lung tissue beyond the site of bronchial obstruction. Marked bronchiolitis is depicted with fibrous thickening of the bronchiolar wall and marked inflammatory infiltration. The adjoining lung tissue is atelectatic, and there is a severe chronic pneumonitis with fibrous thickening of the alveolar walls and infiltration by chronic inflammatory cells (lymphocytes, plasma cells, and macrophages). *D*, chronic atelectasis and pneumonitis.

inflamed and edematous bronchus. In a smaller group of patients (six) there were no enlarged lymph nodes in the hilum of the middle lobe, the bronchial obstruction apparently having been produced by edema and inflammation of the bronchial wall only. In eight patients, large calcified lymph nodes were found around the middle lobe bronchus. In several of these patients there was a complete ring of calcified nodes surrounding the bronchus. There is no question that these calcified lymph nodes were producing extrinsic pressure on the bronchus thus inducing obstruction. In four patients these stony lymph nodes had eroded partially through the bronchial wall (Fig. 1). This process, if allowed to continue, would undoubtedly result in a broncholith. Secondary to the bronchial obstruction complete or partial atelectasis occurs together with chronic infection. A chronic pneumonitis and fibrosis supervenes. Bronchiectasis eventually develops distal to the bronchial obstruction. Bronchiectasis, however, is not a prominent feature of the pathology but is only secondary to long-standing bronchial obstruction. It is considered entirely probable that inflammation and edema of the bronchial wall undoubtedly contribute to bronchial obstruction of the middle lobe bronchus, thus inducing atelectasis in the absence of extrinsic pressure by enlarged peribronchial lymph nodes or calcified lymph nodes. In two patients the bronchial obstruction was due to a foreign body reaction in the bronchial wall.

SYMPTOMATOLOGY

The cardinal symptoms of chronic atelectasis and pneumonitis of the middle lobe consist of chronic cough, pain, hemoptysis, dyspnea, and wheeze. Chronic cough was present in all of the thirty-two patients. In seven patients the cough was worse in dorsal recumbency, that is the patients complained of the fact that on lying down at night they developed severe coughing which was relieved by sitting in an upright position. Twenty-one of the thirty-two patients had pain which was usually located in the anterior portion of the chest, in many instances near the midline. Intermittent hemoptysis occurred in fourteen of the thirty-two patients. Hemoptysis varied from frank blood spitting to blood streaking of the sputum. Dyspnea was present in eight of the thirty-two patients, and a definite wheeze was described by the patient in six instances. Previous pneumonias constituted a prominent part of the clinical history. Twenty patients had had a previous pneumonia, nineteen of whom had had a pneumonia diagnosed two or more times. Fifteen patients complained of a constant low-grade fever. Eleven patients complained of easy fatigability. Frequent colds and loss of weight were present, respectively, in seven patients. Table I illustrates the incidence of these symptoms.

TABLE I. SYMPTOMS AND FEATURES OF THE CLINICAL HISTORY OF THIRTY-TWO PATIENTS

SYMPTOMS	NO.	HISTORY OF	NO.
Cough	32	Pneumonia	20
In dorsal recumbency	7		
Pain	21	Low-grade fever	15
Hemoptysis	14	Easy fatigability	11
Dyspnea	8	Frequent colds	7
Wheeze	6	Loss of weight	7

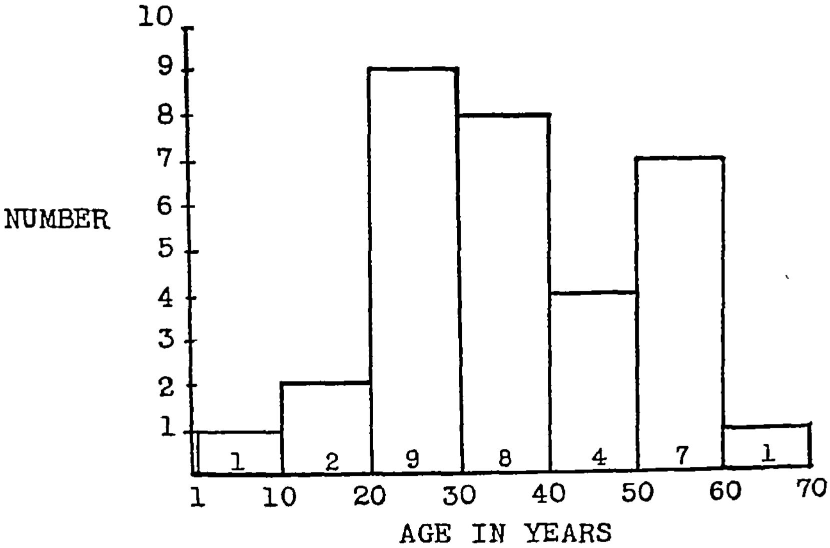
The duration of symptoms is illustrated in Table II and varied from five months to twenty years. It is to be noted that twenty-six patients had had symptoms for one or more years and that seventeen patients had symptoms for three or more years.

TABLE II. DURATION OF SYMPTOMS

UNDER 1 YR.	1 TO 2 YR.	3 TO 5 YR.	5 TO 12 YR.	20 YR.
6	9	10	6	1

The incidence as to sex revealed an almost equal division between males and females, 17 being males and 15 females. The age of these patients varied from 7 years to 62 years. Table III illustrates the age grouping.

TABLE III. AGE INCIDENCE



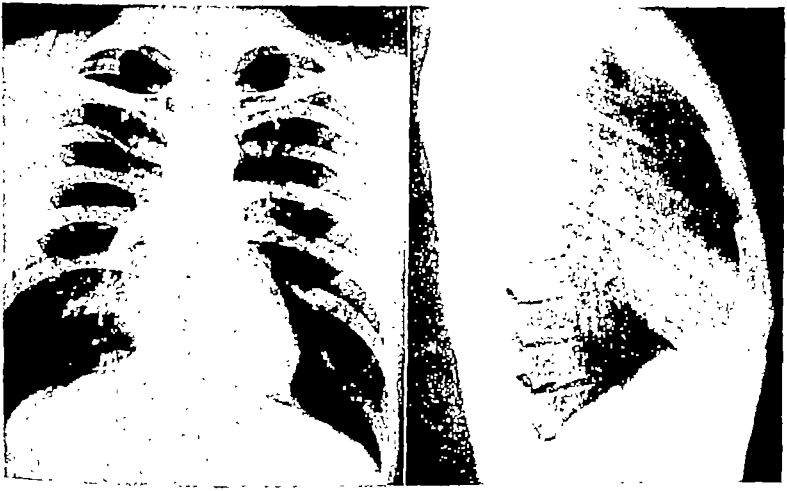
OBJECTIVE FINDINGS

The bronchoscopic findings consist of an edema, hyperemia, or induration of the mucosa of the bronchus to the middle lobe. Purulent secretion was seen arising from the middle lobe orifice, and in many patients the opening was markedly narrowed and slit-like in appearance. Some patients obtained temporary relief from the symptoms following a bronchoscopy performed for diagnosis. The bronchoscopic findings are not diagnostic alone but are of considerable value when taken into consideration with a careful history, roentgenographic and bronchographic findings.

TABLE IV. BRONCHOGRAPHIC FINDINGS

	NO.
Complete obstruction of bronchus	12
Incomplete filling of one segment	7
Close grouping of bronchi	4
Bronchiectasis	5
Total	28

The roentgenographic and bronchographic findings are very important in the diagnosis of chronic atelectasis and pneumonitis of the middle lobe. It is necessary to make right lateral roentgenograms in addition to the conventional posteroanterior and anteroposterior exposures. In many instances the atelectasis will not be visible on the conventional posteroanterior exposure only to be very obvious on the right lateral exposure (Fig. 2). An atelectasis of the middle lobe was diagnosed by the roentgenologist in nineteen of thirty-two patients and in five patients there was an area of increased density visible in the region of the middle lobe. Plain roentgenograms (including posteroanterior and lateral exposures), in other words, led us to the diagnosis in twenty-four of the thirty-two patients. Complete bronchography was done in twenty-eight patients. The bronchogram revealed complete obstruction of the right middle lobe bronchus in twelve patients and incomplete filling of one of the two segments of the middle lobe in seven patients. In four patients, although the bronchi of the middle lobe were filled with oil, close grouping of the bronchi was demonstrated, indicative of atelectasis. Bronchiectasis was demonstrable by bronchogram in only five patients. Bronchography demonstrated either obstruction of the bronchi of the middle lobe or close grouping of the bronchial branches in twenty-three of twenty-eight patients (Fig. 3).



A.

Fig. 2.—Posteroanterior and right lateral roentgenogram of the chest of three different patients illustrating: *A*, the absence of a shadow in the posteroanterior exposure and the evident segmental atelectasis in the lateral exposure; for *B* and *C* see the following page.

DIAGNOSIS

The diagnosis of chronic atelectasis and pneumonitis of the middle lobe is based upon a careful history, the bronchoscopic, roentgenographic, and broncho-

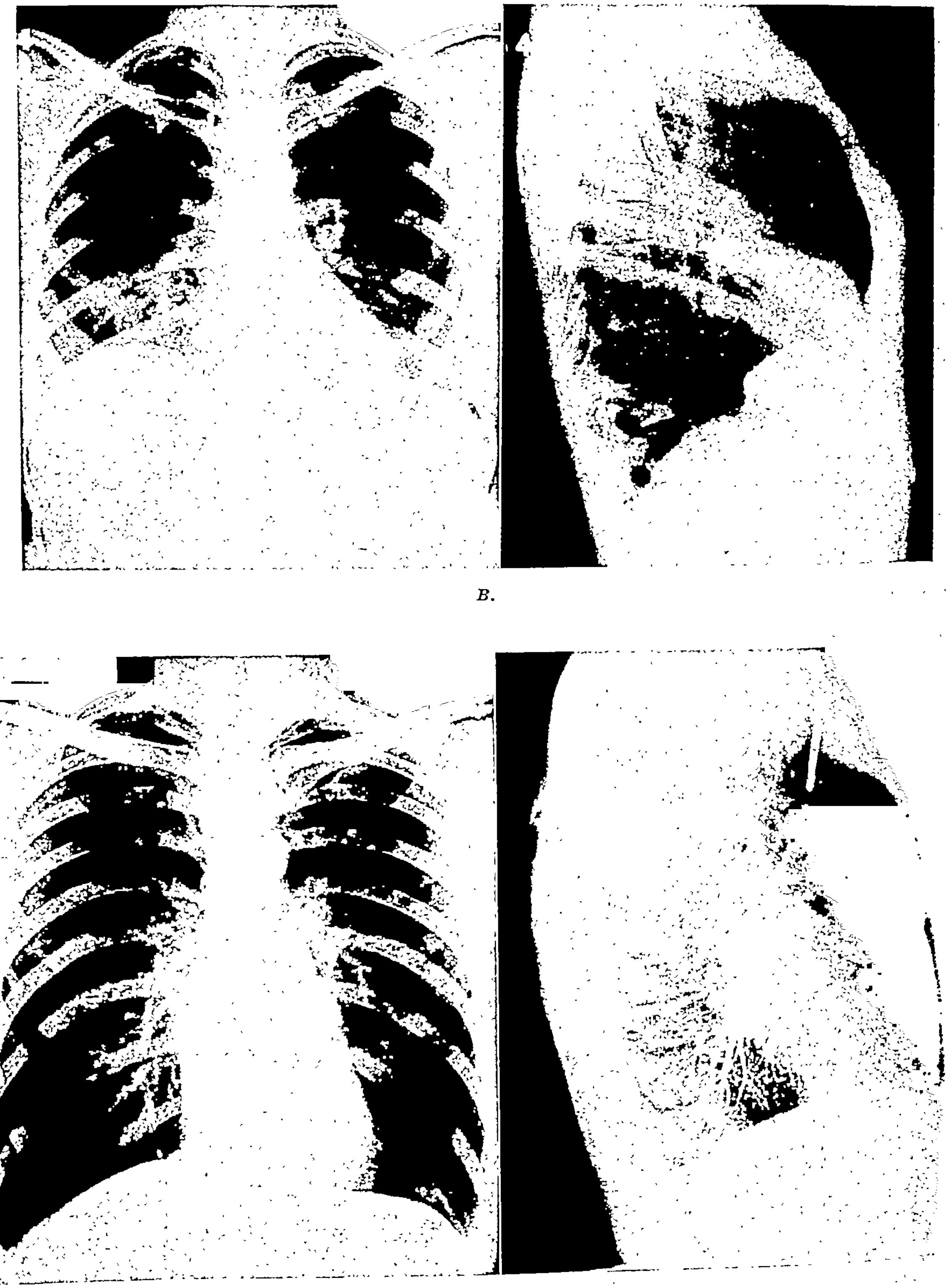


Fig. 2.—For *A* see preceding page; *B*, an area of the middle lobe in the right lateral films, due to calcification within the hilum; *C*, Normal appearance of chest in posteroanterior film but obstruction of bronchus to the middle lobe bronchographically.

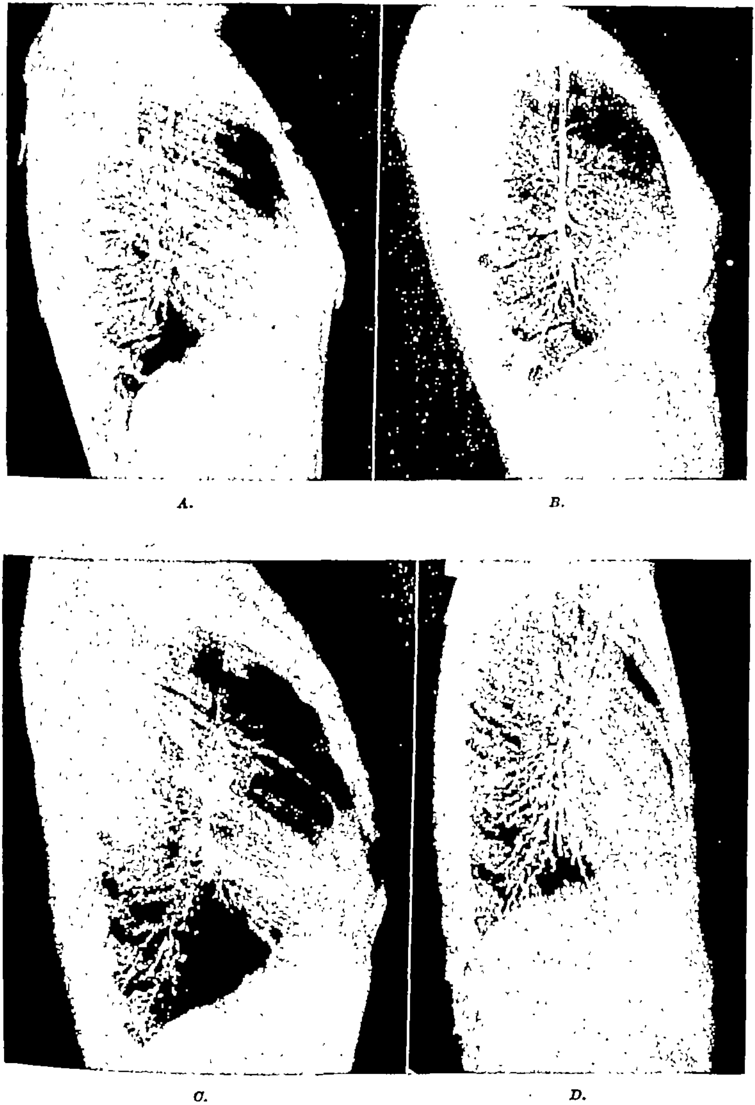


Fig. 3.—Right lateral bronchograms of four patients illustrating: *A* and *B*, obstruction of middle lobe bronchus; *C*, obstruction of one of the two segments of the middle lobe (the same patient as Fig. 2 *A*); *D*, close grouping of bronchi of the middle lobe.

graphic findings. Any patient giving a history of chronic cough which may be worse in dorsal recumbency accompanied by right anterior chest wall pain and hemoptysis and with a history of recurrent pneumonias, a low-grade fever, and easy fatigability should be considered as possibly having chronic atelectasis and pneumonitis of the middle lobe. Bronchoscopy may suggest the presence of this condition. Plain roentgenograms taken in the posteroanterior and lateral views in many instances will give confirmatory evidence. A complete bronchogram should be made in all patients in order that the remainder of the bronchial tree may be studied as well as the middle lobe. Definite obstruction of the middle lobe bronchi or close grouping of the bronchial branches in those patients in whom the bronchi fill with lipiodol will be visualized in a high percentage of patients suffering from chronic atelectasis and pneumonitis of the middle lobe.

OPERATIVE FINDINGS

Because chronic atelectasis and pneumonitis of the middle lobe is a type of chronic suppurative disease from which there is no hope of recovery, surgery is indicated. A right middle lobe lobectomy was done in twenty-nine of the thirty-two patients. At the time of the operation, complete atelectasis of the middle lobe was found in fourteen patients and partial atelectasis in twelve patients. The lymph nodes surrounding the middle lobe bronchus were unusually large, inflamed, and indurated in fifteen patients. These lymph nodes were calcified in an additional eight patients. In four of these eight patients the calcified material extended into the bronchial lumen. Inflammatory adhesions were present between the visceral and parietal pleura adjacent to the middle lobe in many instances, and in several patients there were dense adhesions between the middle lobe and pericardium and diaphragm. It is entirely possible that the adhesions between the middle lobe and pericardium account for the pain which the patient experiences near the midline anteriorly.

The results of operation have been satisfactory on the whole. Of the twenty-nine patients undergoing a right middle lobectomy, one patient died. This was a 51-year-old man who died on the fourth postoperative day from a pulmonary embolus. There were no postoperative empyemas. One patient developed an organized hemothorax secondary to bleeding. It was necessary to perform a decortication of the remaining portions of the right lung three weeks later. This patient eventually obtained a satisfactory result. Three patients continue to have a slight cough associated with a generalized bronchitis. Two patients have had a recurrence of hemoptysis. One of these patients has a long bronchial stump and it is believed that the bleeding occurs from ulceration of the mucosa within this long bronchial stump. It is believed that the recurrence of hemoptysis in the second patient is due to a rather severe generalized chronic bronchitis.

DISCUSSION

The syndrome of chronic atelectasis and pneumonitis of the middle lobe is presented as a newly recognized clinical entity of pulmonary suppurative disease. Justification for its separation as a clinical entity is occasioned by the frequency with which this syndrome is encountered together with the characteristic pattern of this type of suppurative disease. *It cannot be classified* as bronchiectasis. Although bronchiectasis is frequently reported by the pathologists, *the principal feature of the disease is obstruction of the middle lobe* bronchus with chronic atelectasis and pneumonitis. Although a chronic pneumonitis develops as a result of atelectasis, the condition should not be classified as a lung abscess.

Chronic atelectasis and pneumonitis may occur in any portion of either lung. We believe that various mechanical factors peculiar to the anatomy of the bronchial tree tend to favor the development of bronchial obstruction and atelectasis of the middle lobe more frequently. The right middle lobe bronchus arises from the intermediary bronchus at almost a right angle in the lower portion of the chest. For this reason, drainage is poor. The main bronchus of the middle lobe is also very short and branches after a distance of less than 1 cm. into two main segments. The diameter of these segmental bronchi is normally small. It is entirely possible that as a result of pneumonia there will be inflammation and edema within the wall of these small bronchi. Because of their small diameter, they are easily obstructed. Originating from the remainder of the bronchial tree at almost a right angle, drainage is poor, and atelectasis may readily develop. Two-thirds of the patients in this series gave a history of a pneumonia, almost all of whom had had pneumonia two or more times. It has been our opinion that the first pneumonia perhaps damaged the bronchial wall thus resulting in bronchial obstruction. The lymph nodes of the middle lobe bronchus almost completely surround it. Expansion of an enlarging lymph node within the hilum of the middle lobe is limited medially by the pleural reflection from lung to pericardium in the region of the anterior pulmonary vein and anteriorly by the pulmonary artery as it crosses the bronchus of the middle lobe transversely to its length. As these lymph nodes become inflamed and enlarge secondary to the inflammation within the middle lobe, further pressure is exerted on the bronchus from the outside. If the bronchus is already weakened by inflammation and edema, it is entirely possible that the bronchial wall will be compressed by extrinsic pressure. This then develops into a vicious cycle, the bronchial obstruction inducing more infection within the middle lobe and the infection within the middle lobe inducing further swelling of the enlarged lymph nodes surrounding the middle lobe bronchus. There can be no question of the etiological factor involved in the eight patients in whom enlarged calcified lymph nodes were found *surrounding the middle lobe bronchus.* In some instances the middle lobe bronchus was surrounded by a ring of calcium. In four patients the calcified nodes had partially eroded through the bronchial wall.

The same set of circumstances may come into play in other portions of the lung, although because of the mechanical factors outlined here, the middle lobe appears to be more commonly involved. Four patients having chronic atelectasis and pneumonitis of the lingular segment of the left upper lobe have been treated during this same period of time. Three of these patients had an obstruction of the lingular bronchus (bronchographically) associated with enlarged peribronchial lymph nodes, and in one patient the obstruction was due to a calcified lymph node. Chronic atelectasis and pneumonitis of the right upper lobe due to enlarged calcified lymph nodes about the right upper lobe bronchus were encountered in one patient.

During the last three years we have done 168 pulmonary resections (exclusive of total pneumonectomies) for various types of pulmonary inflammatory disease. Twenty-nine of these were done for chronic atelectasis and pneumonitis of the middle lobe. Exclusive of lung abscess, bronchiectasis, and specific types of pneumonitis, chronic atelectasis and pneumonitis of other portions of lung constituted the indication for resection in twelve patients.

Graham, Burford and Mayer,* presented a paper entitled "The Middle Lobe Syndrome" before the Interstate Postgraduate Assembly in October, 1947. At that time they presented twelve cases and also were of the opinion that the middle lobe syndrome justified separation as a clinical entity.

The diagnosis of chronic atelectasis and pneumonitis of the middle lobe is not a difficult diagnosis to make if one is aware of the possibility. The most important condition in its differential diagnosis is bronchiogenic carcinoma. In all instances in which a preoperative diagnosis of chronic atelectasis and pneumonitis in the middle lobe is made, the possibilitiy of a bronchiogenic carcinoma must be kept in mind, particularly in patients in the older age group.

It is believed that many patients complaining of chronic cough, chest pain, and hemoptysis have had only plain posteroanterior roentgenograms made and given a diagnosis of bronchitis. Such a patient should have the benefit of a lateral roentgenogram and a complete bronchogram. A careful history and complete bronchography will reveal signs of middle lobe obstruction in some of these patients. Even though a complete bronchogram be done, lack of filling of the middle lobe bronchus is too often easily explained on the basis of technical failure. If there is any question concerning technique, the bronchogram should be repeated. If as a result of a second bronchogram, oil does not enter the bronchus of the middle lobe or one of its segments, a positive diagnosis of bronchial obstruction should be made. The procedure, of course, necessitates doing complete bronchography with careful attention to all bronchial segments

The treatment of chronic atelectasis and pneumonitis of the middle lobe is surgical. The mortality and morbidity in this series were low. Because of the possibility of a bronchiogenic carcinoma, surgery is imperative in the patients in the older age group. Pulmonary emphysema and an obstructive bronchitis will probably develop if the localized area of atelectasis and pneumonitis is allowed to persist over many years. It is our opinion that as soon as it becomes obvious that the atelectasis and pneumonitis are chronic a pulmonary resection should be done.

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*Graham, Evarts A., Burford, Thomas H., and Mayer, John H.: The Middle Lobe Syndrome, Postgrad. Med. 4: 29-34, 1948.

SUMMARY

A review of thirty-two patients having chronic atelectasis and pneumonitis of the middle lobe is presented. The cardinal symptoms of this condition are cough, anterior chest wall pain, hemoptysis, dyspnea, and wheeze. A history of recurrent pneumonias, low-grade fever, easy fatigability, frequent colds, and loss of weight is obtained in a high percentage of patients. Pathologically the condition is characterized by chronic atelectasis and pneumonitis of the middle lobe secondary to bronchial obstruction. The bronchial obstruction is the principal etiological factor in the development of the chronic atelectasis and pneumonitis. The frequency and the characteristic diagnostic pattern of this type of pulmonary suppurative disease justifies its separation as a clinical entity.

DISCUSSION

DR. JOHN H. MAYER, Kansas City, Mo.—We too have been impressed by the increasing number of patients with chronic nontuberculous atelectasis of the right middle lobe. Drs. Graham, Burford, and I have had the opportunity recently to report our experience in thirteen such cases. The symptomatology, x-ray, and bronchoscopic findings have been essentially the same as in the cases reported here today. Hemoptysis has been the presenting complaint in the majority of our patients. We are in complete agreement with Dr. Paulson as to the importance of the lymph nodes about the middle lobe bronchus in effecting constriction of that bronchus. The strategic location of these nodes and their importance in the etiology of nontuberculous bronchiectasis have been emphasized by Brock in his recently published book on the anatomy of the tracheobronchial tree. (Slide.) This illustration was taken from his book and demonstrates, as Dr. Paulson has told you, the location of the lymph nodes about the origin of the right middle lobe bronchus.

Because these cases began to make their appearance at a time when penicillin was coming into widespread use it occurred to us that these patients might represent the residua of extremely severe acute suppurative infection from which the patients would not have recovered except with the help of penicillin. However, in reviewing our cases we found that many of them had never received penicillin and most of them had not had a severe acute onset. Our concept is that no one specific etiological agent can be indicted, but that any disease producing pulmonary lymphadenopathy may be at fault.

I think it may be worth while to point out that these lymph nodes represent to a large extent lymph drainage from the lower lobe on the right side and that one must be careful that the right lower lobe is free of disease prior to attacking the middle lobe surgically. In one of our patients we subsequently had to remove chronic suppurative disease of the right lower lobe, the right middle lobe having been successfully removed six or eight months previously.

DR. RALPH A. DORNER, Des Moines.—I have seen a number of patients who fit into this syndrome. I would like to mention one patient who presented a very typical clinical and x-ray picture. While operating on her after freeing the hilus of the middle lobe, I noticed that the bronchus to the middle lobe was very thick. Previously, the bronchoscopy had shown a comma-shaped narrowing of the bronchus to the middle lobe. I was afraid, when we found this thickening of the bronchus, that perhaps something had been missed on the bronchoscopy. I, therefore, opened the bronchus and, to my amazement, a peanut fell from the bronchus. There was a nest of granulation tissue around the nut accounting for some of the thickening of the bronchus and the narrowing of its orifice. Thus the point was brought to mind that even though the picture may fit the syndrome which Drs. Graham, Burford, and Mayer described earlier, we must consider that patients may have foreign bodies within the bronchus producing a clinical picture of the "middle lobe syndrome."

DR. ARTHUR S. W. TOUROFF, New York.—I have observed, and operated upon, a number of cases similar to those reported by Dr. Paulson and Dr. Shaw, and I am in agreement with practically everything that they have said. I have been impressed with the difficulties that may arise in connection with making a diagnosis in older patients, and especially with ruling out the diagnosis of malignancy. Carcinoma of the middle lobe is not particularly common; and yet if the patient is in the so-called ''cancer age'' and has hemoptysis and clinical symptoms of pulmonary infection, as well as roentgenographic evidence of atelectasis, one cannot dismiss lightly the diagnosis of carcinoma. Nevertheless, the presence of calcific glands should always make one suspicious of the presence of a nonmalignant lesion. It is interesting to note that in a number of our cases, bronchoscopy has been entirely negative and that, under such circumstances, bronchography has been of great value in clarifying the diagnosis. In such cases, the stenotic area is situated too far distally in the middle lobe bronchus to be seen by the bronchoscopist. If lipiodol is instilled into the bronchus, it is not uncommon to note, in the bronchogram, an area of bronchial narrowing which may be one-half inch or more in length. This is in distinct contrast to the complete occlusion of the bronchus or the short area of bronchial narrowing that usually is seen in cases of malignancy. In certain cases, it may be quite impossible to rule out the diagnosis of malignancy prior to operation, and under such circumstances, surgical exploration rather than ''watchful waiting'' is indicated. Furthermore, in certain cases even after the thorax has been opened, it may be impossible to differentiate between a chronic inflammatory lesion of the middle lobe and a malignancy. In a number of cases of this type, I have been forced to rely upon the result of frozen-section examination; for that reason, it is well to have the pathologist present in the operating room whenever the diagnosis has not been made with certainty prior to operation. This simple expedient has, on several occasions, permitted us to rule out the diagnosis of malignancy and proceed with simple removal of the middle lobe rather than pneumonectomy.

DR. CLARENCE CRAFOORD, Stockholm.—It might be of interest to you to hear that it is not only in Anglo-American countries that cases of this type occur. We have had a number of them also in Sweden. It is to one of the symptoms described here that I want to call attention, that is, hemoptyses. We had one case with very large hemoptyses, and we did not believe that the small middle-lobe lesion that we found in the roentgenogram could be the cause of the abundant bleeding that was present. The patient had had for about 15 or 20 years smaller hemoptysis at intervals, sometimes at intervals of years, but in the last few years he had had a number of hemoptyses so great that he went into unconsciousness at the time of bleeding; the blood loss each time was estimated to be more than 1 liter. At these occasions he was taken to a provincial hospital and when the bleeding had stopped the secondary anemia was treated, after which he felt fairly well and went back to his work. Finally he was sent to us and bronchoscopy was done; when the right main bronchus was entered enormous bleeding began and the patient nearly died. The bleeding, however, could be controlled and localized to come from the middle lobe bronchus on the right side. At operation, the chronic inflammatory reaction in the area of the hilum was such that I encountered technical complications so I had to perform a total pneumonectomy. The specimen afterward showed a very peculiar thing; there was a fistula as big as a slate pencil between the pulmonary artery branch of the middle lobe and the bronchus, and in that hole was a thrombus. We believe that the origin of this fistula must have been a purulent lymph node inflammation with an abscess breaking into both the bronchus and the pulmonary artery.

DR. JEROME HEAD, Chicago.—I believe that we are making a mistake in limiting our discussion to involvement of the middle lobe. The same process, of course, may affect any lobe. As you know, Parrott is remembered because he said that in tuberculosis the hilus lymph glands reflected the lung parenchyma. When I started tuberculosis work, it was common for the roentgenologist to put his hand over the hilus region and say, ''Forget about that area; if you are looking for tuberculosis, look in the parenchyma.'' Increasingly

I have been impressed with the importance of looking to the hilus. Very often parenchymal disease is a reflection of trouble in the root glands. This is true both in tuberculous and in nontuberculous disease. *We are seeing today more primary progressive tuberculosis.* I am certain that in many of these cases severe bronchial tuberculosis develops by extension from involved bronchial lymph glands, and also that extension occurs from these glands into the parenchyma.

Our attention has recently been called to this whole subject of the glands in the mediastinum and the root of the lung by an increasing series of cases in which patients have expectorated calcium. At the meeting in New York in two weeks, Dr. Chester Moen and myself are giving a paper on nontuberculous pulmonary disease secondary to nontuberculous reinfection of calcified glands at the hilus. In our series, this has affected all lobes. Dr. Moen has made 100 dissections in the anatomic laboratory and has found, as other people have found, that the location of these glands is very constant. I shall not go into the details of the anatomy, but would like to mention that Mr. Nelson, whom many of us remember, was one of the first to work out the detailed anatomy of the lymph glands of the hilus of the lung. He was mentioned yesterday in connection with original anatomic work on the segments of the lung lobes.

DR. ALFRED GOLDMAN, Los Angeles.—Many points have been covered regarding this disease. I became interested in it about two years ago and I find that once you begin to look for the effects of calcification in x-ray views of the chest you begin to explain almost all the previously unexplainable symptomatology on the basis of this calcification. As a result, sometimes I think we overdo it, because it is sometimes hard to tell which came first, the lymph nodes or the disease in the lung, and I still am confused myself to know in some cases whether there was bronchiectasis and then the lymph nodes, or whether the lymph nodes came first and bronchiectasis followed. I think that I agree with Dr. Graham and others who feel that the lymph nodes were the primary process in many instances.

(Slides.) Also I agree that this is a disease that requires special attention particularly in the older age group to differentiate it from carcinoma.

This is one of six cases; the base of the right upper lobe was involved. The patient was about 50 years of age, had a small hemoptysis, and it was thought she had carcinoma. Bronchoscopy showed narrowing and bulging and a diagnosis of suspicion of carcinoma was made. I performed exploratory thoracotomy with a diagnosis of carcinoma undetermined. A right upper lobectomy was done.

I urge that when exploration is carried out in such patients not only the pulmonary calcification be taken out but others searched for which may cause further trouble; the chances are that the calcifications produced the hemoptysis in this case. There was also an empyema which produced a large amount of pus in the interlobar space.

It will be noted that the large paratracheal calcification was removed as well as that one penetrating toward the lumen of the right upper lobar bronchus.

This patient made an uneventful recovery and has remained well for the past 1½ years.

DR. DONALD L. PAULSON, Dallas.—We are naturally pleased that others are seeing this condition as well as ourselves. In talking to several men in the last few days they have told us that they have encountered similar cases. As pointed out to us on Monday the term *"obstructive pneumonitis"* is preferable to the term *"chronic atelectasis and pneumonitis."* I believe this is particularly true in this group of cases under discussion this morning.

In regard to foreign bodies within the bronchus, at least two patients in this series had a foreign body reaction in the bronchial wall, both being due to strands of cotton, one in a 53-year-old woman with symptoms of twenty years' duration, and the other in a 7-year-old boy.

We agree that carcinoma is the most important condition to be considered in the differential diagnosis particularly in patients in the older age group. Surgery, of course, is imperative in that group for this reason. In our experience in only one instance have we made a diagnosis of chronic atelectasis and pneumonitis of the middle lobe and found a carcinoma at the time of the operation.

We certainly do see this condition in any portion of either lung. There is nothing specific about the pathology except that it does represent an obstructive pneumonitis. In our experience it does occur much more frequently in the middle lobe and perhaps this is due to the mechanical factors outlined in our discussion here this morning. Because of the frequency with which an obstructive pneumonitis occurs in the middle lobe and because of the characteristic clinical and diagnostic pattern, we believe that this syndrome is worthy of separation as a definite clinical entity.

DR. PAUL C. SAMSON, Oakland, Calif.—Dr. Dugan and I wish to record our experiences with the "middle lobe syndrome." Our interest in these lesions was heightened by discussions with Dr. Thomas Burford at the St. Louis meeting of this Association and by perusal of Brock's excellent monograph. In the past eighteen months, we have cared for seventeen patients with localized bronchiectasis and/or pneumonitis of the right middle lobe. Seven additional patients with bilateral bronchiectasis (in all of whom left-sided resections have been performed) showed, on the right, bronchiectasis only of the middle lobe. During the same period of time we have seen but three patients whose bronchiectasis was limited to the lingula, and three whose bronchiectasis was limited to the anterior segment of the right upper lobe. Of the seventeen patients noted here, fifteen were women and two were men. The majority of our patients with bronchiectasis have been women in the past two years but apparently there is an increased and as yet unexplained sex incidence in the middle lobe group. With the exception of one girl of 19 years whose symptoms dated from babyhood, the remainder first had difficulties in adult life and the average age of the sixteen patients was 51 years (30 to 69 years). Hemoptysis was the presenting symptom in ten; cough, sputum, and febrile episodes in seven.

Ten patients showed bronchiectasis primarily (six with atelectasis) on the basis of bronchograms and surgery; seven patients (four with atelectasis) showed no bronchiectasis following lipiodol instillation. The right middle lobe was resected in five patients; surgery was recommended to another five patients and presently refused (probably until bleeding begins again); in the remaining seven excision was not advised because of age, and improvement following bronchoscopic aspiration and antibiotic therapy.

Of the five patients on whom resection was performed, three showed definite evidence of partial compression of the middle lobe bronchus because of enlarged lymph nodes and in two there was no evidence of bronchial compression.

INTRACAVITARY SUCTION (MONALDI) IN THE TREATMENT OF EMPHYSEMATOUS BULLAE AND BLEBS

Jerome R. Head, M.D., and (by invitation) Edward E. Avery, M.D.
Chicago, Ill.

BULLOUS emphysema is a relatively common and often a seriously crippling condition. The etiology and diagnosis of emphysematous changes in the lungs have received considerable attention in the literature, but the treatment, until very recently, has been seldom mentioned and uniformly considered hopeless.

In 1687 Bartholinus[1] first described a large pulmonary cyst in a 4-year-old boy who died of "marasmus." Sir John Floyer,[2] in 1698, described the cystic alterations in the lungs of broken-winded horses, and his observation would be equally applicable to human beings. Laennec,[3] however, was the first to put pulmonary emphysema upon the list of recognizable diseases and catalogue its symptoms and pathologic changes. Laennec stated that Ruysch and Valsalva had observed the dilatation of pulmonary cells and that Morgagni clearly described this dilatation.

From a review of the literature, there appears to be no uniformity of nomenclature or opinion on the differential diagnosis of cystic lesions of the lung. The terminology apparently depends upon which portion of the clinical or pathologic picture the author is describing.

Congenital pulmonary cysts, congenital and acquired bronchiectasis, epithelial lined cavities following pulmonary suppuration, lung abscess, tuberculous cavities, cavities due to fungus or parasitic infections, spontaneous pneumothorax, and the various types of emphysematous changes of the lungs must all be considered in the differential diagnosis of so-called pulmonary cysts.

Cases of emphysema with emphysematous bullae and blebs have come to our attention with increasing frequency. It is the purpose of this paper to present the results of surgical treatment by intracavitary suction in nine cases showing these emphysematous changes in the lungs.

PATHOGENESIS

The etiology of emphysema is uncertain and its pathogenesis remains subject to extensive investigation. For the purpose of definition, Christie[4] classified emphysema under five types: hypertrophic, or chronic obstructive emphysema; atrophic, or senile emphysema; acute vesicular emphysema associated with acute infections of the respiratory tract; localized, or compensatory emphysema due to atelectasis or fibrosis; and surgical, or acute interstitial emphysema associated with chest injuries or artificial pneumothorax. Of these types, chronic obstruc-

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tive emphysema is probably the most important in the formation of bullous emphysema, although any type could contribute to the check valve mechanism which produces bullae or blebs.

The terms "bullae" and "bleb" are used in this paper as described by Miller.[5] Blebs as well as bullae represent localized air pockets within the lungs. Blebs are located immediately beneath the pleura, while bullae are within the lung tissue itself. In the case of the bleb, air escaping from a ruptured alveolus leaks into the subserous connective tissue layer of the pleura which is composed of collagenous and elastic fibers. The escaping air separates the pleura from the underlying alveoli. He noted advanced emphysema in all cases in which blebs occurred. Bullae are also caused by the rupture of alveoli, but the atrophic and dilated alveoli rupture into each other forming air pockets within the parenchyma of the lung with the pleura retaining its connection with the lung.

Bullae usually occur in patients with chronic bronchitis or asthma, but they are occasionally seen in individuals with no demonstrable respiratory disease. One can speculate that in chronic bronchitis, the infection causes swelling of the walls of the bronchi, and this together with the thick tenacious secretions causes obstruction to free gaseous interchange. This valvular mechanism was found by Hayashi[6] on microscopic examination of bronchi communicating with emphysematous cavities. Spasm of the bronchial muscles in asthma has long been recognized as an important factor in the bronchial obstruction of this disease. Vesicular emphysema with subsequent bulla formation is often seen following a severe pneumonia[7] or lung abscess,[8] where there is necrosis of the alveolar walls. McNeil[9] in studies of pneumonia in children found that 20 per cent of the cases autopsied showed necrosis of the bronchial and bronchiolar walls. This necrosis might lead to rupture and interstitial emphysema, which could dissect into the subpleural layer to form blebs. With these similar pathologic processes occurring in the same area of the lung, rupture and fusion of the blebs and bullae may take place to form huge so-called pneumatoceles.

Compensatory emphysema is seen in atelectasis, and following lobectomy or pneumonectomy.[10] It is also a contributing factor in so-called "senile emphysema" where the chest becomes barrel-shaped with increased thoracic volume.[11, 12]

Normally, the active force of inspiration is greater than the passive action of expiration, but the elastic recoil of the lung and the changes in dynamics of the thorax deflate the unobstructed portions of the lungs. In partial obstruction of the bronchi, a volume of air is drawn into the lung but only a portion of air escapes, thereby creating increased intra-alveolar tension with subsequent stretching, atrophy, and rupture of the walls.[13]

In our studies of bullae through the thoracoscope, we have learned that once tension cavities have formed, the dynamics of their progression are reversed so that the destructive force is now that of expiration instead of inspiration. These large emphysematous cavities are at least partially surrounded by elastic and compressible lung parenchyma, and they are supplied air by tortuous, distorted bronchi. A typical bullous cavity appears as a large air-filled sphere, the base of which is made up of long slender, interlacing strands of black pulmonary tissue. The dome of the cavity is covered with a thin, white membrane of pleura, crisscrossed with a fine capillary network. Through this translucent membrane the rib cage can be seen sliding back and forth with respiration, apparently because of the absence of pleural adhesions. Long filaments of tightly stretched lung tissue may be tented from the walls to the floor of the cavity. During expiration, as the intrathoracic pressure increases, the pressure within the lung becomes greater than within the bulla. The parenchyma can be seen to bulge into the cavity toward the scope where many minute bronchial openings can be seen to appear among the strands of tissue. At the height of expiration, with the tip of the scope near the openings, the lens becomes fogged by the incoming moist air.

During inspiration, as the intrathoracic pressure decreases, the walls of the cavity expand because the pressure within them is greater than in the remainder of the lung. The parenchyma can be seen to recede from the scope, and the pores disappear as the web of lung fibers become compressed on one another. The tortuous bronchial openings to the cavity become more obstructed as the surrounding parenchyma is compressed by the expanding cavity, and air is thus trapped within the bulla. Coughing or straining against the closed glottis exaggerates this check valve mechanism so that pressures within the cavity have been measured as high as plus 50 mm. of mercury. Blebs present essentially the same picture except that the major portion of the cavity wall is made up of thin pleura. There is a smaller area of denuded lung, and there are fewer bronchial fistulas than are usually seen in bullae.

It is apparent that emphysematous changes in the lungs are due to complex processes. *Any one or all of the afore-mentioned factors, as well as many* unknown mechanisms, may contribute to the formation of bullae and blebs.

Emphysema is found in 2 to 5 per cent of all autopsies.[4] It seems probable that bullous emphysema may become a more pressing medical problem in the future, as the antibiotics permit more persons to survive severe respiratory infections, and as more people live into the later decades of life.

CLINICAL PICTURE

The symptomatology depends upon the underlying pathologic processes and the resultant physiologic changes. Because of the nature of emphysema, bullae and blebs usually are multiple, often are bilateral, and symptoms tend to progress. Although some cases are entirely without symptoms and are discovered on routine chest x-ray examinations, the majority of patients' complaints are referable to chronic bronchitis or asthma, which are known to be associated with emphysematous changes. The presence of a large air space, essentially nonfunctional, can cause dyspnea and cyanosis by replacing space normally occupied by functioning lung. The total capacity, as well as the vital capacity, is reduced.[14] The thorax may increase in size on the side of the lesion and the diaphragm become depressed to cause further mechanical impairment of the respiratory bellows. The *intercostal spaces are widened, and the affected side lags on inspiration.* The belbs or bullae may reach sufficient size to cause mediastinal shift and circulatory embarrassment. It is not uncommon for these patients to die of anoxia.

Chest pain is not infrequent and may be due to tension or to adhesions caused by readjustments of the lung due to pressure from bullae.

Infection in bullae and blebs is extremely rare, in contrast to the frequency with which this complication is seen in other types of pulmonary cysts. We have seen only two cases where this developed. These were apparently due to active inflammatory processes in the lung immediately adjacent to the bullae.

Emphysema and decreased respiratory reserve lead to obstructed pulmonary circulation,[15] high pulmonary arterial pressure, and hypertrophy of the right side of the heart.[16] With cor pulmonale the peripheral venous pressure increases,[17] and the patient with far-advanced bullous emphysema may present himself with the symptoms of right heart failure.

Spontaneous pneumothorax is by far the most frequent and dangerous of the sequelae. It is often recurrent and is the most common cause of death in the cases of bullous emphysema reported in the literature.[18-26] Leach[27] has recently demonstrated that the etiology of spontaneous pneumothorax is due almost entirely to the rupture of emphysematous blebs and bullae, and only rarely due to tuberculosis, which was once thought to be the major cause of this complication.

X-RAY FINDINGS

Blebs and bullae appear on the x-ray films as areas of decreased density or increased brilliancy. They cause annular, ring-shaped shadows with fine, hairline borders which are in contrast to the heavy borders seen in inflammatory excavations.[28-32] A slight haziness is often noted around a smaller bulla, and above or below a larger bulla, due to compression atelectasis of the adjacent parenchyma. The bullous spaces may be crisscrossed with lacy filaments of lung tissue. In advanced bullous emphysema the tension cavities which produce the so-called "vanishing lung"[33-34] may be difficult to differentiate from complete pneumothorax. The heart and mediastinum may be displaced toward the normal side, and the diaphragm on the affected side depressed and flattened. In pneumothorax the elasticity of the lung causes it to contract around the hilus, forming a rounded stump. However, with large bullae the hilar shadow appears narrow and elongated by compression, or may not be seen at all, and the lung can be pushed peripherally where its shadows may be seen in the apex or costophrenic angle. Furthermore, in spontaneous pneumothorax there is likely to be fluid in the pleural cavity. Another differential clue was pointed out by Korol,[35] who noted that there was a narrowing of the intercostal spaces due to the decreased intrapleural pressure of chronic pneumothorax, whereas there was a widening of the rib cage in the expansile cavities of emphysema.

It is important to remember that the routine chest film often fails to reveal emphysematous cavities. This is particularly true where the cavities are in the base of the lung. In this location their contours may be covered by bronchial markings of lung which may lie in front or in back of the cavity. Where bullae or blebs are suggested, it has been our practice to take several oblique and lateral views. The films are exposed a few kilovolts lighter than normally calculated because of the decreased density of these lungs.

RATIONALE OF TREATMENT

Emphysematous bullae and blebs require treatment because they are causing recurrent or chronic pneumothorax or because they are compressing the lung and causing incapacitating dyspnea.

The surgical attack may be directed toward release of pressure and the reversal of the check valve mechanism by drainage, the closure of the bronchial communications, or the excision of the diseased portions of the lung.

Early attempts at treatment of tension cavities by thoracentesis gave only temporary relief of symptoms[38-39] and was often followed by shock, tension pneumothorax, and death.[40, 41]

Lilienthal[42] in 1929 reported the alleviation of symptoms of a tension cyst by temporary tube drainage with the use of a one-way valve. Croswell[43] reported another case of giant cyst treated in a similar manner. The cyst collapsed to about one-fourth its original size, and the patient's clinical symptoms disappeared. Brown and Brock[44] treated a large "balloon" cyst by continuous suction drainage with gradual collapse of the cavity. Drainage was continued by making an Eloesser endocutaneous flap[45] until the lung was completely re-expanded.

Thoracoplasty was suggested[46] and used in a few cases without beneficial results. Chondrectomy was proposed by Freund[47] to relieve the intrathoracic pressure seen in emphysematous changes of the lung. This procedure failed as it obviously ignored the basic pathology and allowed additional expansion of the lung.

Lipiodol injected into the cavities was sometimes followed by relief of symptoms. This may have been due to blocking of the bronchial fistulas with oil or by inflammatory changes.[43, 48, 49] Sclerosing solutions have also been suggested.

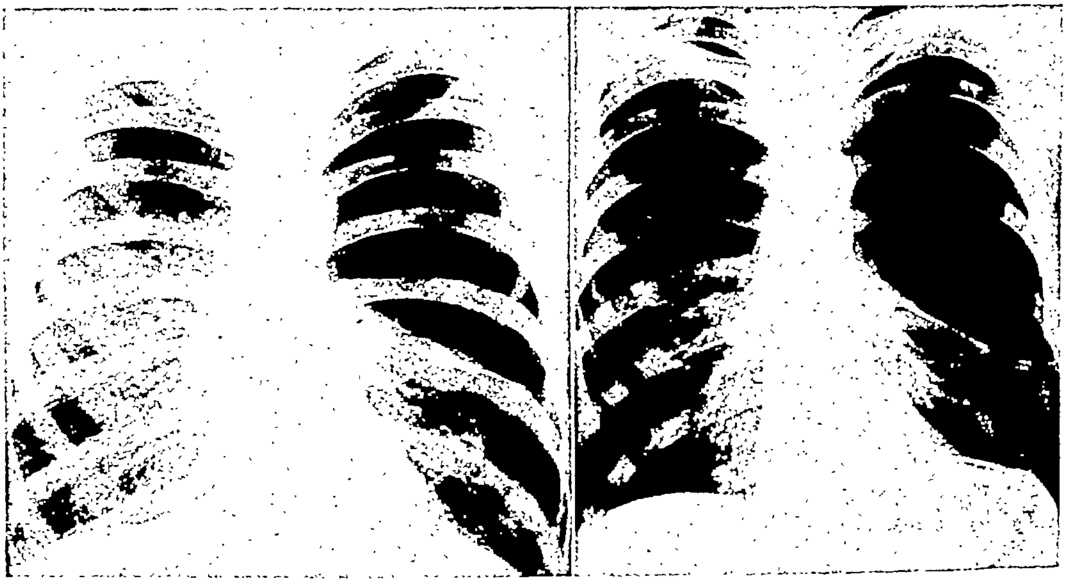
Transthoracic closure of bronchial fistulas in tension cysts was described by Wood in 1934.[49] Recently Naclerio and Langer[50] reported an additional four cases treated in a similar manner where they used the walls of the bulla or bleb to cover the defect in the lung. We have treated one case by excising the roof of the bleb and re-expanding the lung with suction drainage.

Excision of bullae is not surgically possible because there is no epithelial lining or cleavage plane. However, segmental resection, lobectomy, or pneumonectomy may be performed if the disease is not too extensive or bilateral. Recurrent pneumothorax and chronic tension pneumothorax, due to rupture of blebs or bullae, often force the hand of the surgeon to exploratory thoracotomy. The method of treatment then depends upon the findings, which often cannot be accurately predetermined until the chest is opened. Tyson,[51] Meade,[52] and Clagett[53] have used this approach successfully.

Transthoracic exploration should be avoided, if possible, as thoracotomy alone may produce inflammatory changes of the lung and pleura that may seriously impair vital capacity which may already have reached minimum functional tolerance.[54]

Because some of our patients with large bullae were in such critical condition, major surgery could not be undertaken, and it was felt that intracavitary drainage was the only procedure that they would tolerate. *Our initial efforts* met with such success that we have now come to regard it as the procedure of choice in most cases.

The point of optimum drainage is chosen by studying the various x-ray views and selecting a site where the bleb is adjacent to the chest wall. Under local anesthesia, an extrapleural exploration is done to determine whether or not there is pleural symphysis. In every case to date a free pleural space has been found, and it has been necessary to produce adhesions with gauze packing before the catheter could be inserted. The constancy of this finding suggests that the absence of pleural adhesions is necessary for the formation of the blebs. It seems probable that the inflammation which produces adhesions fixes the visceral pleura so that it cannot be separated.



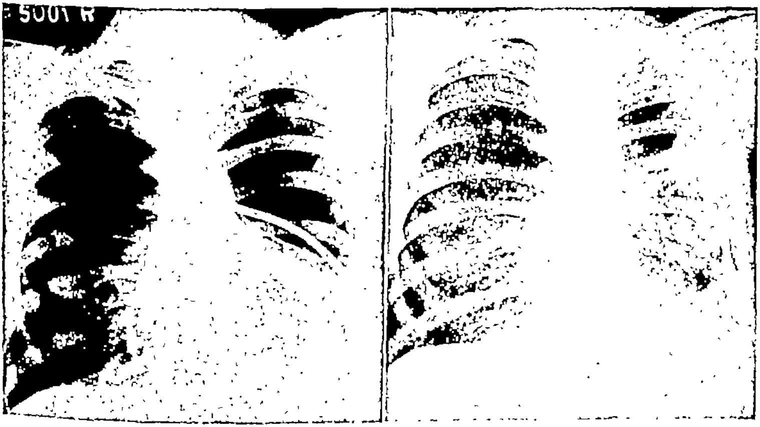
A. *B.*

Fig. 1, *A* and *B* (Case 1).—*A*, Chest x-ray film taken July, 1945, showing absent lung markings in upper two-thirds of left side of chest and beginning changes in right apex. *B*, Film of December, 1946, showing progression of disease.

The gauze pack is removed as a second stage procedure, and the wound is allowed to heal before proceeding with the catheter insertion. Pressure readings are then recorded, a thoracoscopic examination is done, and biopsies are taken, if feasible. A multiple fenestrated catheter is then placed well into the cavity, sealed at the skin edges with an airtight dressing, and connected to a water-seal bottle. If air continues to escape through the bottle and the lung has shown no evidence of re-expansion after a few days, a Stedman suction pump is added and adjusted to maintain a negative pressure of minus 10 to 20 cm. of water. Re-expansion has usually occurred in one to three weeks. The catheter is allowed to remain in place an additional few days to cause inflammatory obliteration of the space. The mechanism of re-expansion is believed to be twofold; the vicious cycle of events causing a check valve tension cavity is broken by substituting a gentle, physiologic, negative pressure which allows the re-expansion of surrounding, compressed, atelectatic lung; the catheter acts as a foreign body causing effusion and inflammatory closure of the bronchial fistulas. Gross infection, which was a stumbling block to this type of treatment in the past, can now be controlled with antibiotics.

It should be pointed out that this type of treatment is difficult because it requires considerable time, meticulous attention to details, and persistence in drainage to obtain re-expansion of the lung. The results, to date, have been gratifying, but it will be necessary to carry out a long follow-up study on these patients to determine the outcome of this type of procedure.

Intracavitary suction drainage does not give satisfactory results in epithelial lined cysts which are better treated by excision. We have inadvertently drained this type of cyst in the past. In future cases, where the differential diagnosis is not possible preoperatively, we feel that careful thoracoscopic examinations should be performed, and biopsies taken if necessary, before the ultimate type of therapy is decided.

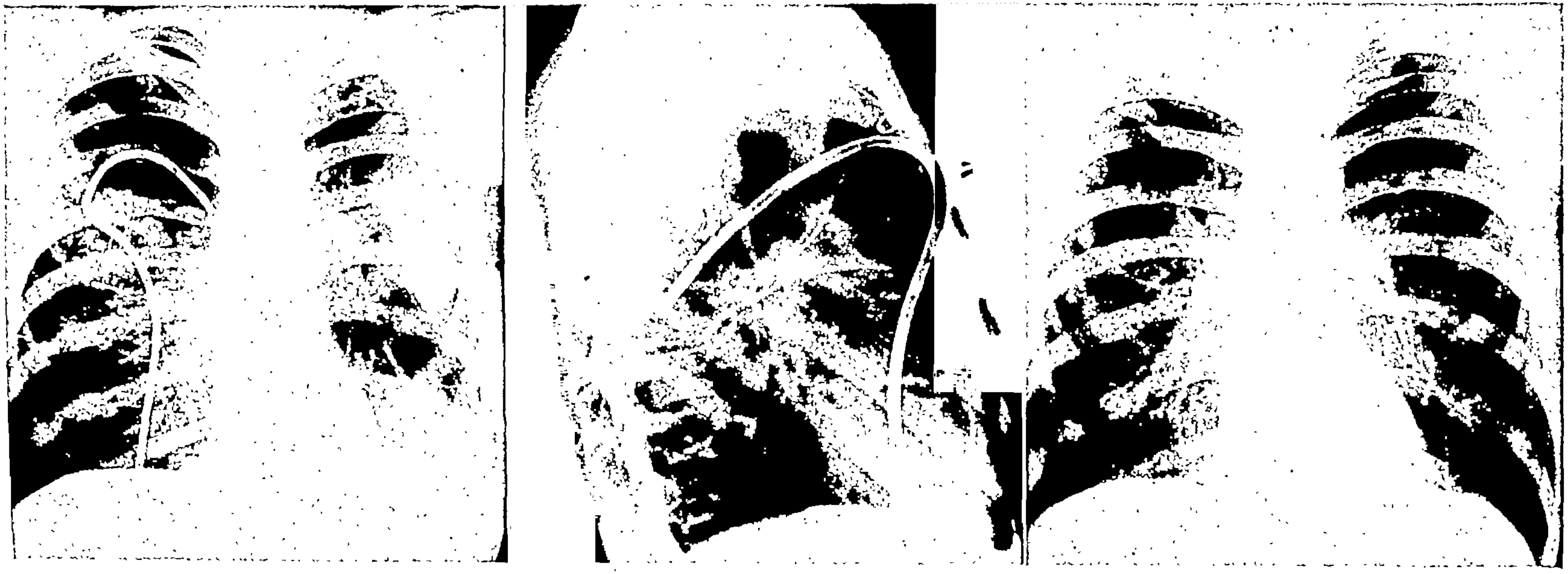


C. *D.*

Fig. 1. *C* and *D* (Case 1).—*C*, Catheter in left bullous cavity. *D*, Bullae decompressed; left lung expanded.

CASE REPORTS

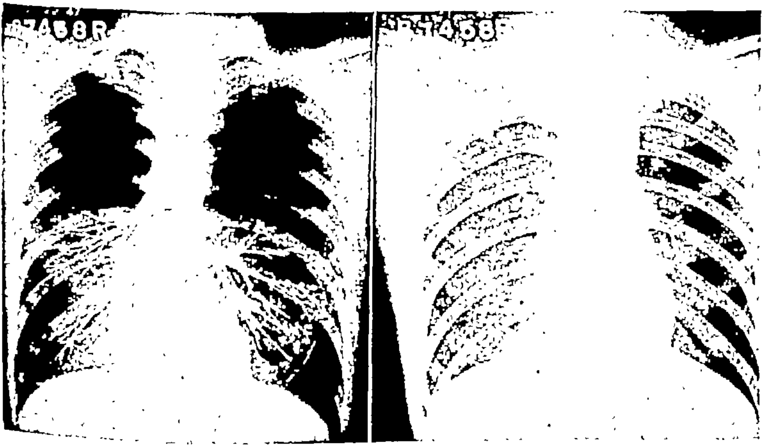
Case 1.—R. G., a 50-year-old white man, was admitted January, 1947, with a history of chronic severe dyspnea and acute abdominal distention. He had been previously hospitalized for treatment of asthma and chronic appendical abscess. The patient stated that the asthma had become progressively worse during the past five years and that he had a constant cough productive of small amounts of thick, sticky sputum. He was *bedfast* because of dyspnea and said that he had been taking 10 to 20 c.c. of adrenalin daily by nebulizer to help him "reach for his wind." Hospital work-up revealed a partial intestinal obstruction and far-advanced bullous emphysema. In a review of x-ray films taken July, 1945, there was noted absence of lung markings in the upper half of the left side of the chest and a slight decrease in markings in right upper lung field (Fig. 1 *A*). The film of



E. *F.* *G.*

Fig. 1, *E*, *F*, and *G* (Case 1).—*E*, Catheter in right bullous cavity. *F*, Lateral view showing catheter in bulla. *G*, Postoperative film with both lungs re-expanded.

the present admission showed progression of the disease so that lung markings were now absent in the upper three-fourths of the left side of the chest and the upper half of the right side of the chest (Fig. 1 *B*). At exploratory laparotomy adhesions were cut to relieve the small bowel obstruction. *After a stormy postoperative course, the patient was transferred* to the Thoracic Surgery Service where it was decided that intracavitary suction was the only possible form of therapy that the patient might tolerate. The vital capacity was 950 c.c. The usual three-stage Monaldi procedure was carried out on the left side, as it was necessary to produce pleural symphysis before insertion of the catheter. Intracavitary pressure readings were recorded at plus 10 minus 8 mm. Hg on quiet expiration and inspiration. With coughing the needle swung to plus 50 (as high as the machine registered) and back to minus 20 on deep inspiration. Thoracoscopy revealed a huge bullous cavity similar to a picture of these cavities described previously. Biopsy of the wall of the cavity revealed inflammatory tissue, pleura, and a few distorted alveoli. The diagnosis was compatible with that of bullous emphysema. A catheter was then placed in the bulla and connected to a water-seal bottle (Fig. 1 *C*). Re-expansion of the left lung occurred in ten days with a resulting increase in vital capacity to 1,800 c.c. (Fig. 1 *D*). The same procedure was done on the right side (Fig. 1 *E* and *F*) where a similar cavity was found. The right lung re-expanded, except for a small apical portion, after three weeks of water-seal drainage, but the catheter became twisted and was removed. Another catheter was reinserted into the residual cavity at a later date. Continuous suction drainage by Stedman pump was necessary for an additional four weeks to obtain maximum re-expansion (Fig. 1 *G*). The patient's vital capacity was then increased to 3,350 c.c. Skin sensitization tests were all negative for extrinsic allergens. He is now capable of carrying on full daily activity and has had no complaints except for very occasional asthmatic attacks.



A. *B.*

Fig. 2 (Case 2).—*A*, Bronchogram showing depression of upper lobe bronchi from bilateral apical blebs. *B*, Postoperative x-ray film following decompression of blebs.

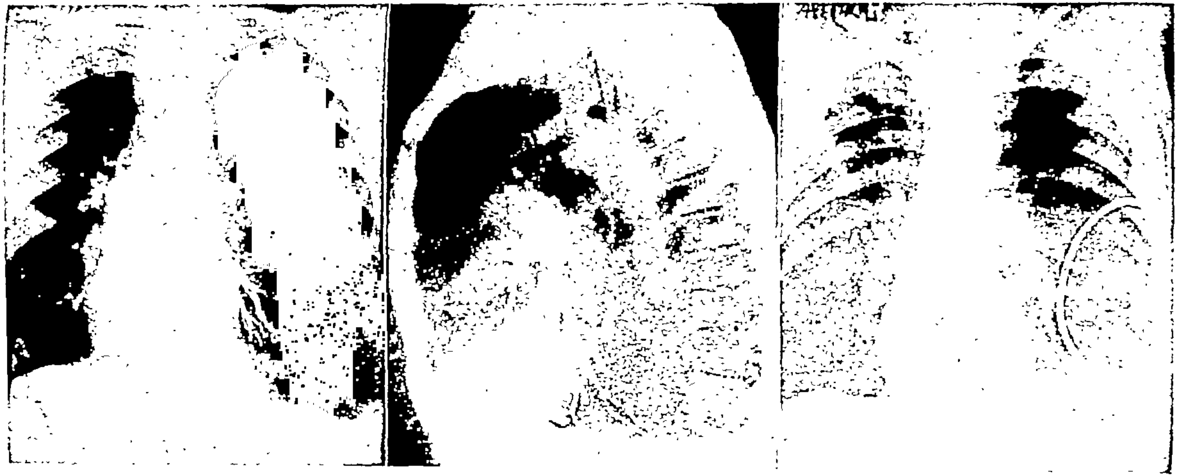
Case 2.—G. R., a white man, 31 years of age, was admitted October, 1947, with complaints of gradually increasing dyspnea for the past four years, and pain in the right upper side of the chest for one month. He had been discharged from the Army in 1944 with a diagnosis of cystic disease of the left lung. X-ray examination revealed absent lung markings in the upper two-thirds of the left side of the chest and the upper half of the right side of the chest. Bronchograms showed the compression of the upper lobe bronchi toward the bases of the lung (Fig. 2 *A*). Because of this depression it was possible to see several centimeters into both upper lobe bronchi at bronchoscopy. The usual three-stage Monaldi procedure was started on the left side. Thoracoscopy revealed a huge spherical cavity with thin, whitish translucent walls. An area 3 cm. in diameter at the base of the cavity showed some gray, shredded lung tissue with only a few visible bronchial communications. Because of this small area of denuded lung, it was felt that the diagnosis was compatible with that of emphysematous bleb. The bleb was decompressed, except for a small apical portion, within three weeks. The catheter then became twisted and had to be removed. It was found that the fenestrations in the tubing had been made too large and allowed the walls to collapse. An attempt was made to place a catheter in the residual portion of the bleb, but because of lack of pleural symphysis a surgical pneumothorax was obtained. After the lung had re-expanded a catheter was successfully placed in the bleb and it was quickly decompressed. The thoracoscopic findings in the right side of the chest were similar to those described on the left. Catheter suction drainage resulted in complete re-expansion of the right lung in two weeks (Fig. 2 *B*). The patient's vital capacity was increased to 3,350 c.c., and he was able to carry on vigorous activity without dyspnea.

CASE 3.—E. M., a 62-year-old white man, was admitted December, 1947, with complaints referable to chronic bronchitis and arthritis. The patient had had symptoms of chronic cough for ten years and gradually increasing dyspnea for the past two years. X-ray examination revealed absent lung markings in the upper one-third of the right side of the chest with some herniation of the mediastinum toward the left. Vital capacity was 1,370 c.c. Monaldi drainage was carried out with re-expansion of the right lung in four weeks. Biopsy revealed pleura and a few atrophic alveoli. The diagnosis was compatible with that of emphysematous bulla. Vital capacity was increased to 2,530 c.c.

CASE 4.—S. S., a 31-year-old Negro man, was admitted July, 1947, with symptoms of epigastric distress and pain in the left upper side of the chest. He was discharged from the Army with a diagnosis of chronic pneumothorax on the left. Complete gastrointestinal work-up was negative. Chest films revealed absence of lung markings in the upper one-third of the left side of the chest. Thoracoscopic examination showed bullous changes similar to those described previously. Decompression by electric suction pump was accomplished in the usual manner in three weeks. Vital capacity increased from 2,080 c.c. to 3,400 c.c.

CASE 5.—J. R., a 45-year-old white man, was admitted June, 1945, for treatment of peptic ulcer and chronic bronchitis. Ulcer symptoms were relieved with medical management. X-ray examination revealed two large emphysematous cavities in the left upper lobe with some evidence of old inactive tuberculosis. There was a small amount of fluid in the anterior cavity. Examinations for tuberculosis were all negative. The anterior cavity was decompressed with Monaldi drainage in three weeks. The fluid within the space proved to be sterile. Diagnosis from biopsy of the cavity wall was compatible with that of bulla. The patient refused further surgery and was discharged at this time.

CASE 6.—J. O. B., a 68-year-old white man, was admitted December, 1945, for treatment of severe dyspnea. He complained of asthmatic attacks and progressive dyspnea for twenty years. The patient was cyanotic even with maximum respiratory effort while sitting in a wheel chair. X-ray examination revealed absence of lung markings in the left side of the chest with the mediastinum shifted to the right. Bronchograms showed the terminal branches of the left bronchial tree compressed against the mediastinum (Fig. 3 *A*) and pushed anteriorly by a tension cavity located posteriorly (Fig. 3 *B*). Vital capacity was 800 c.c. After an extrapleural pack was inserted, the patient became more cyanotic and sank into coma. Because of the patient's extreme condition it was felt that decom-



A. B. C

Fig. 8 (Case 6).—*A*, Bronchogram revealing absent lung marking on the left, compression of the bronchial tree, and shift of the mediastinum. *B*, Lateral film showing anterior compression of the bronchial tree and the posterior location of the emphysematous tension cavity. *C*, X-ray film during suction drainage demonstrating re-expansion of left lung.

pression was necessary at once. The gauze packing was removed one week after it had been placed in the extrapleural space, and a trocar and catheter were advanced into the cavity. The patient improved for one day and then showed signs of increasing dyspnea. X-ray pictures revealed the catheter in the bulla and also a tension pneumothorax. The pneumothorax was apparently due to a lack of pleural symphysis which allowed air to escape around the catheter into the pleural space. The pneumothorax was quickly decompressed by inserting another catheter. Re-expansion of the left lung was accomplished in one month (Fig. 3 *C*). When recently contacted, the patient was found to be active about his home.

CASE 7.—O. H., a 10-year-old white boy, was admitted for treatment because a routine chest film revealed a complete absence of lung markings in the left side of the chest, with a shift of the mediastinum to the right. The boy was completely asymptomatic and engaged in strenuous athletics. A three-stage drainage was done and a catheter placed into the cavity through the anterior part of the chest. Within a few days fluid, containing gram-negative organism, developed in the cavity and temperature went up to 104° F. Another large catheter was placed in the base of the cavity posteriorly. The fever mitigated and the cavity gradually reduced in size. At discharge, the left lung had re-expanded except for a small space in the left base containing a little fluid. The patient remains asymptomatic, and careful follow-up study is being carried out by periodic x-ray examinations. Because of the marked reaction following the insertion of the catheter it was believed that this may possibly have been an epithelial-lined cyst. This mistake could be avoided in the future by careful thoracoscopic study of the cavity and biopsy of the wall.

CASE 8.—W. M., a 52-year-old white man, had been hospitalized for over one year for incapacitating dyspnea. Asthmatic attacks began five years previously. Dyspnea had been progressive in the past two years. The patient was cyanotic and dyspneic at bed rest even when using all accessory muscles of respiration. There were findings of early right heart failure. Laboratory studies indicated a marked secondary polycythemia. The routine x-ray examination showed far-advanced emphysematous changes with areas of decreased density (Fig. 4 *A*). Bronchial markings could be seen extending to the periphery of the lung fields. However, the oblique (Fig. 4 *B*) and lateral films (Fig. 4 *C*) revealed definite bullous cavities. Catheters were inserted in the usual manner, into large bullae at both bases with decompression obtained in two weeks (Fig. 4 *D*). The patient has been relieved of some of the dyspnea and is semiambulant. Catheter drainage is contemplated for the remaining several large bullae. In advanced, multiple, bilateral bullae, there is a question of how long the patient will be benefited, and how often the procedure will have to be repeated. The fact remains however, that the patient is much improved at present.

CASE 9.—L. C., a 28-year-old white man, was admitted with symptoms of marked dyspnea on exertion. The patient was discharged from the Army in 1941 with a diagnosis of cystic disease of the right lung. He had had no symptoms referable to his chest up until that time. X-ray examination revealed only scattered markings in the right side of the chest and a definite displacement of the mediastinum (Fig. 5 *A*). After adhesions were produced, thoracoscopic examination revealed many thin-walled cavities that appeared like "soapsuds," which would rupture and coalesce when touched with the tip of the scope. A catheter was inserted (Fig. 5 *B*), but very little benefit was derived. Because of these findings an exploratory thoracotomy was done. Multiple cystic degeneration of the entire right lung was found and a pneumonectomy performed (Fig. 5 *C*). The patient states that his "wind" is now better than ever before in his life.

SUMMARY AND CONCLUSIONS

1. Patients with bullous emphysema are being seen by the thoracic surgeon with increasing frequency. In the past, the surgical treatment of emphysematous blebs and bullae has been considered hopeless.

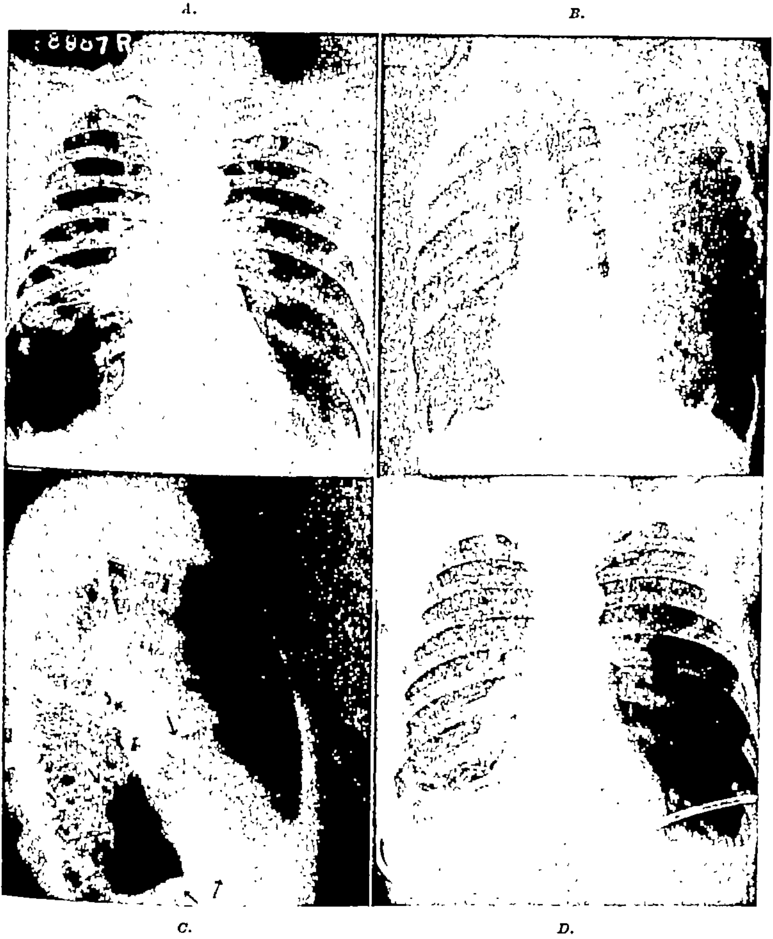
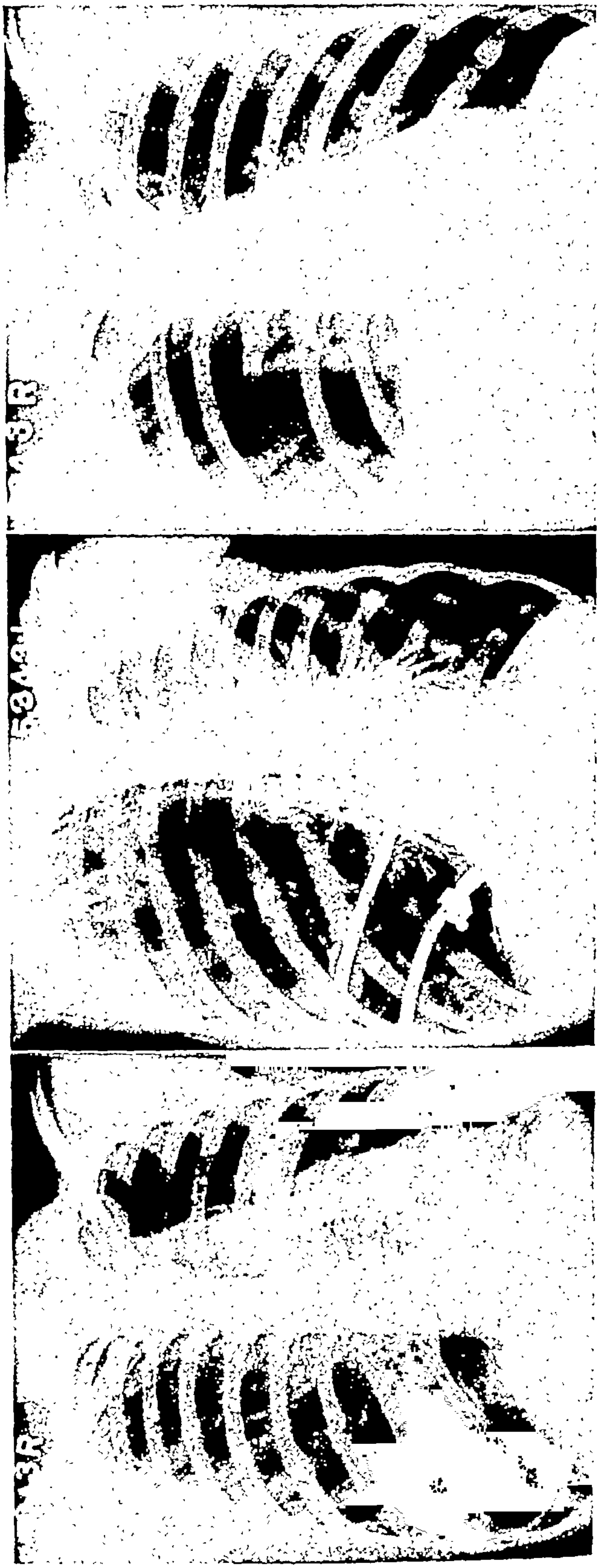


Fig. 4 (Case 3).—*A*, Bilateral severe emphysematous changes, with no definite cavities visible. *B*, Oblique film reveals absent lung markings at both bases. *C*, Right lateral x-ray film shows large bullous cavities. *D*, Catheters in bullae during decompression.



A. B. C.

Fig. 5 (Case 9).—*A*, Only scattered lung markings in right side of chest with mediastinal shift and pronounced herniation. *B*, Catheter in right cystic lung with very little re-expansion; note compression of right bronchial tree. *C*, Postoperative x-ray film following pneumonectomy. Mediastinum has returned to normal position and the compressed left lung has re-expanded.

2. The pathogenesis of tension cavities and their check valve mechanism is discussed. The x-ray and clinical picture is outlined.

3. The methods of treatment are reviewed and the intracavitary suction drainage procedure is presented. It is believed that this is the procedure of choice in certain types of emphysematous cavities. Eight cases are presented in which gratifying results have been obtained by this method.

REFERENCES

1. Bartholinus, T.: In M. Malpighi Opera Omnia, London, 1687, R. Littlebury, pp. 340-350.
2. Floyer, Sir John: Treatise on Asthma, 1698.
3. Laennec, R. T. H.: Treatise on Diseases of the Chest and on Mediate Auscultation, 1819.
4. Christie, R. V.: Emphysema of the Lung, Brit. Encyc. Med. Pract. 4: 508-519, 1937.
5. Miller, W. S.: A Study of the Human Pleura Pulmonalis; Its Relation to the Blebs and Bullae of Emphysema, Am. J. Roentgenol. 15: 399-407, 1926.
   Idem: A Further Study of Emphysematous Blebs, Am. J. Roentgenol. 18: 42-47, 1927.
   Idem: The Lung, Springfield, Ill., 1937, Charles C Thomas, Publisher.
6. Hayashi, J.: Ueber Totlichen Pneumothorax durch Infarkt und Emphysem. Frankfurt. Ztschr. f. Path. 16: 1-30, 1914.
7. Benjamin, B., and Childe, A. E.: Localized Bullous Emphysema Associated With Pneumonia in Children, J. Pediat. 15: 621-632, 1939.
8. Oechsli, W. R.: Postoperative Bullae Following Lung Abscess, Am. J. Roentgenol. 52: 145-148, 1944.
9. McNeil, C., MacGregor, A. R., and Alexander, W. A.: Studies of Pneumonia in Children, Arch. Dis. Childhood 4: 111-124, 1929.
   Idem: Bronchiectasis and Fibrosis of Lung, Arch. Dis. Childhood 4: 170-189, 1929.
10. Longacre, J. J., and Johansmann, R.: An Experimental Study of the Fate of the Remaining Lung Following Total Pneumonectomy, J. THORACIC SURG. 10: 131-150, 1940.
11. Freund, W. A.: Der Einfluss der Brimaren Erkrankougen des Knorpligen Thorax auf Entstehung Gewisser Lungenkrankhaiten, Verhandl. d. phys.-med. Gesellsch. zu Würzb. 9: 2231, 1859.
12. Loeshke, H.: Handbuch der Speziellen Pathologischen Anatomie und Histologie, Vol. 3, Pt. 1, Hencke, F. & Leubarsch, O., 1928.
13. Best, C. H., and Taylor, N. B.: Physiological Basis for the Practice of Medicine, Baltimore, 1945, Williams & Wilkins Company.
14. Kaltreider, Nolan L., and Fray, Walter W.: Pathological Physiology of Pulmonary Cysts and Emphysematous Bullae, Am. J. M. Sc. 197: 62-73, 1939.
15. Hamman, L.: Emphysema, in H. A. Christian, Oxford Medicine, Vol. 2, Part 1, New York, 1940, Oxford University Press, pp. 68-81.
16. Scott, R. W., and Garvin, C. F.: Cor Pulmonale (Role of Emphysema) Observation in 50 Autopsy Cases, Am. J. Heart 22: 56-63, 1941.
17. Kountz, W. B., Alexander, H. L., and Dowell, D.: Emphysema Simulating Cardiac Decompensation, J. A. M. A. 93: 1369-1371, 1929.
18. Cummer, C. L.: Recurrent Pneumothorax; Report of a Case, With Review of the Literature, Am. J. M. Sc. 150: 222-227, 1915.
19. Kjaergaard, Hans: Spontaneous Pneumothorax in the Apparently Healthy, Acta med. Scandinav., supp. 43, pp. 1-159; 1-93, 1932.
20. Lewis, N.: Chronic Bilateral Spontaneous Pneumothorax, Brit. M. J. 2: 779-780, 1933.
21. Oechsli, W. R., and Miles, S. H.: Simultaneous Bilateral Spontaneous Pneumothorax, Am. Rev. Tuberc. 30: 230-255, 1934.
22. Korol, E., and Ensign, O. F.: Bullous Emphysema or Bilateral Pneumothorax, Radiology 23: 223-227, 1934.
23. Willcox, A., and Foster-Carter, A. F.: Spontaneous Pneumothorax, Associated With Bullous Emphysema, Lancet 2: 315-317, 1937.
24. Edwin, G. S.: Extreme Bulla Formation, Brit. J. Tuberc. 31: 293-295, 1937.
25. Harris, H. J.: Extensive Destruction of Lungs: Emphysema With Giant Bullae; Autopsy, Radiology 36: 492-494, 1941.
26. Adams, R.: Fatality From Rupture of Emphysematous Bleb After Subtotal-thyroidectomy, Lahey Clin. Bull. 2: 214-219, 1942.
27. Leach, J. E.: Pneumothorax in Young Adult Males, Arch. Int. Med. 76: 264-268, 1945.
28. Evans, W. A.: Significance of Annular Shadows, Am. J. Roentgenol. 6: 510-512, 1919.
29. Sampson, H. L., Heise, F. H., and Brown, L.: A Study of Pulmonary and Pleural Annular Radiographic Shadows, Am. Rev. Tuberc. 2: 664, 1919.
30. Amberson, J. B.: The Nature and Differentiation of Pleural Annular Shadows, Am. J. Roentgenol. 12: 438-443, 1924.

31. Arnell, S.: Annular Shadows in the Lungs Caused by Subpleural Emphysema, Acta radiol. 8: 252-256, 1927.
32. Laurell, H.: Ein Beitrag Zur Der Sogenannten Ringshatten in den Lungen, Acta radiol. 10: 72-119, 1929.
33. Burke, R. M.: Vanishing Lungs, Radiology 28: 367, 1937.
34. Allison, Stanton T.: The Vanishing Lung: Report of a Case of Advanced Bullous Emphysema, Ann. Int. Med. 17: 139-148, 1942.
35. Korol, E.: Paradoxical Breathing, Arch. Int. Med. 51: 272, 1933.
36. Anspach, W. E., and Wolman, I. J.: Large Pulmonary Air Cysts of Infancy, Surg., Gynec. & Obst. 56: 635-645, 1933.
37. Pearson, E. F.: Cystic Disease of Lung, Illinois M. J. 67: 28, 1935.
38. Schenck, S. G.: Diagnosis of Congenital Cystic Disease of the Lung, Arch. Int. Med. 60: 1, 1937.
39. Sellors, T. H.: Congenital Cystic Disease of the Lung, Tubercle 20: 49, 114, 1938.
40. Parmelee, A. H., and Apfelbach, C. W.: Congenital Air Cyst of the Lung, Am. J. Dis. Child. 41: 1380-1388, 1931.
41. Debre, R., and Blinder, H.: Volumineux Kyste Broncho-pulmonaire Chez un Unfant de Quinze Ans., Bull. et mém. Soc. méd. d. hôp. de Paris 48: 818-823, 1932.
42. Lilienthal, H.: Cyst of Lung, Arch. Surg. 18: 292, 1929.
43. Croswell, C. V., and King, J. C.: Congenital Air Cyst of the Lung, J. A. M. A. 101: 832-834, 1933.
44. Brown, A. L., and Brock, W.: A Method of Treatment of Large Pulmonary Air Cysts (Balloon Cysts) by an Endocutaneous Flap, J. THORACIC SURG. 11: 617-631, 1942.
45. Eloesser, L.: Operation for Tuberculous Empyema, Surg., Gynec. & Obst. 60: 1096, 1935.
46. Eloesser, L.: Congenital Cystic Disease of the Lung, Surg., Gynec. & Obst. 52: 747-758, 1931.
47. Freund, W. Z.: Zur Operativen Behandlung Gewisser, Lungenkrankheiten, Insbesondere des auf Starrer Thoraxdilatation Beruhenden Alveolaren Emphysems, Ztschr. f. exper. Path. u. Therap. 3: 479, 1936.
48. King, J. C., and Harris, L. C., Jr.: Congenital Lung Cyst, J. A. M. A. 108: 274, 1937.
49. Wood, H. G.: Congenital Cystic Disease of Lungs, J. A. M. A. 103: 815, 1934.
50. Naclerio, Emil, and Langer, Lazaro: Pulmonary Cysts. Special Reference to Surgical
51. Tyson, M. D.: Surgical Management of Solitary Cysts or Cyst-like Structures of Pulmonary Origin, Ann. Surg. 118: 50, 1943.
52. Meade, R. H.: Personal communication.
53. Clagett, O. T.: Surgical Treatment of Emphysematous Blebs and Bullae, Dis. Chest 15: 669, 1949.
54. Adams, W. E.: Differential Pressures and Reduced Lung Function in Intra-Thoracic Operations, J. THORACIC SURG. 9: 254-262, 1940.

(See discussion on page 798.)

REVIEW OF SEVEN YEARS' EXPERIENCE WITH INTRACAVITARY (MONALDI) DRAINAGE OF TUBERCULOUS CAVITIES

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INTRODUCTION

IN DISCUSSING Dr. Head's[1] paper on intracavitary drainage before this Association in 1944, one of us (W. W.)[2] presented a summary of our results on 35 patients treated up to that time. Our series now represents 100 cavities in 90 patients who were accepted for intracavitary drainage between August, 1940, and Dec. 31, 1947. While treatment of 11 of these patients was begun during 1947, and thus their follow-up study has been limited, the remainder have been observed for one to seven years. The size of the group and the period of observation warrant this report.

In July, 1938, Monaldi[3] and his collaborators at the Carlo Forlanini Institute first described this method of treating tuberculous cavities. It consists in catheter drainage and the application of suction. While previously many surgeons had drained an occasional tuberculous cavity, the method was not extensively used until these modifications increased its simplicity and effectiveness. It is now a valuable adjunct to our surgical armamentarium in the treatment of certain tuberculous cavities. Since the original report, this method has been tried and studied in many countries, and Monaldi[4] stated that some 400 articles concerning it have now appeared in the world literature.[5-39] In support of this procedure, he has stressed certain theoretical considerations concerning cavities, the most important of these being that the size of a cavity may be out of all proportion to the amount of excavated lung. A tuberculous cavity arises from caseation of the pulmonary parenchyma with subsequent evacuation of the debris. A cavity enlarges by progressive evacuation of its caseous center and/or because of mechanical factors. These mechanical factors are both endocavitary and extracavitary.

The endocavitary pressure depends upon the patency of the draining bronchi. Many authorities feel that if a bronchus is completely blocked, air will be absorbed from the cavity and the walls will tend to approximate. More commonly, the affected bronchus is only partially closed by granulation or scarring and acts as a ball valve, making it possible for air to enter during inspiration but difficult to escape during expiration. In such a case, the intracavitary pressure becomes positive and the cavity tends to enlarge, become spherical, and may have a fluid level. This enlargement results in compression of the adjacent lung parenchyma. Such cavities have been variously termed pressure,[32] tension,[33] blocked,[31] or insufflation[35] cavities. When successive films show alteration in the size of the cavity without evidence of extension of dis-

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ease, the presumption is strong that the variation in size is due to changes in the intracavitary pressure.

The extracavitary factors which tend to keep a cavity open are those forces which exert traction from the outside. First, the normal lung is under constant tension to fill the larger hemithorax. Second, every inspiration by a normally functioning thoracic cage and diaphragm increases this tension. Third, when the mediastinum is distorted toward the opposite side because of disease, tension is increased. Fourth, scarring and fibrosis of lung parenchyma tend to increase tension on adjacent areas. All of these are extracavitary forces which tend toward cavity enlargement.

Theoretically, it would seem that the ideal case for drainage would be a large round cavity with or without a fluid level, with an adjacent area of compressed lung, and with little surrounding disease. In our experience this type has frequently responded dramatically to drainage, but we have succeeded in closing some in which there was no demonstrable positive pressure within the cavity. In other cases, although the cavity did not change appreciably in size, the patient experienced marked symptomatic relief from the decrease in cough and expectoration and the subsidence of toxic symptoms.

INDICATIONS

Although Monaldi[4] used this method as an independent procedure and stated that with it alone he had treated "approximately 100 patients who for some years have been back at work, enjoy perfect health and display no symptoms of illness," our indications have differed and have been similar to those presented to this Association by Head[1] and by Vineberg[1, 32] in 1944 and by Welles and Gordon[36] in 1947.

We have used intracavitary drainage primarily as a salvage procedure either for palliative relief in far-advanced bilateral cases or in the hope that by its use the patient might be prepared for more definitive surgery. A major indication has been the possibility of reducing the size of a large cavity preliminary to thoracoplasty in the hope that the thoracoplasty would need to be less extensive and would be more successful.

The extent to which it has been employed as a palliative procedure may be appreciated by considering the fact that all but one patient had contralateral involvement at some time. In most instances the contralateral disease was extensive. In 46 patients there was cavity, some form of collapse, fluid, or empyema on the contralateral side.

We have used it where there was acute tuberculosis or recent spread. Frequently it has been of little value in such cases, but there have been instances where the resultant improvement has rendered thoracoplasty or resection feasible.

It has also been used in certain patients in whom respiratory reserves were too limited to justify collapse or resection. In all questionable cases we have been guided by the advice of Dr. George Wright, who has undertaken the necessary pulmonary function studies in his laboratory of pulmonary physiology at Trudeau Sanatorium. In two patients age was a relative indication, in that they were considered unsuitable for thoracoplasty.

Attempts were made to introduce catheters into residual postthoracoplasty cavities in 3 patients. Technically this has been difficult. In one the catheter could not be introduced on two attempts. The second was later converted to a cavernostomy. A third is too recent to evaluate. It is dangerous to insert a large trocar into a narrow slitlike cavity close to the mediastinum. One such attempt in 1948 was followed by fatal hemorrhage. Even if successful, one would expect only symptomatic improvement because of the rigidity of the regenerated thoracic cage. We feel, however, that this is an indication when resection or revision is not feasible.

Drainage is now employed as a preliminary to thoracoplasty for any large cavity, because such cavities are notoriously resistant to collapse by any type of thoracoplasty. The effectiveness of prethoracoplasty drainage in reducing the size of cavities has been observed by many surgeons.[32, 30] In our hands, when there has been a long interval between the anterior resection and the subsequent posterior thoracoplasty, the extent of thoracic collapse has been limited by the regeneration of the anterior rib ends. Our attempt to modify this will be described under Technique.

Table I presents an analysis of the indications in our series, and it will be seen that practically every case presented more than one indication.

TABLE I. INDICATIONS
(Frequently More Than One)

1. Bilateral pulmonary tuberculosis			89
Opposite side had:			
Cavity	27		
Unexpanded pneumothorax	8		
Empyema	4		
Thoracoplasty	6		
Paraffin plombage	1		
		46	
2. Large cavity*			51
3. Cavity with acute spread of disease			39
4. Limited respiratory reserve			11
5. Age of patient			2
6. Previous unsuccessful thoracoplasty			3
7. Refused thoracoplasty			1

*Most have had positive intracavitary pressures, but we have been unable to determine this fact except by manometric readings. X-ray interpretation has frequently been unreliable.

After the decision to perform intracavitary drainage has been reached, there are certain practical considerations, the most important of which are the size and location of the cavity. It is technically difficult to introduce a trocar into a small cavity. A large tension cavity in the upper lobe with little surrounding disease is the ideal indication. It allows the tube to be inserted anteriorly where it interferes the least with subsequent thoracoplasty. Lower lobe cavities should be approached posteriorly. This has many disadvantages. The chief one is that the location of the tube interferes with the normal thoracoplasty or resection incision; second, the motion of the scapula has resulted in dislodging the catheter on several occasions; and third, a catheter in this position is frequently uncomfortable. Three patients having posterior drainage have had thoracoplasty and resection.

Aspiration of a cavity at the apex of the lower lobe through an anterior incision has been successfully accomplished in several instances, but we have abandoned it as we feel it carries an unjustifiable risk because it is impossible to be certain that the interlobar fissure is obliterated. Our two operative fatalities occurred in this group, the first from hemorrhage following the wounding of a branch of the pulmonary artery in the middle lobe, and the second from a pneumothorax due to traversing an unobliterated interlobar fissure. The subsequent empyema proved rapidly fatal.

For many of the patients subjected to intracavitary drainage, the only alternative would have been cavernostomy. Drainage is simpler and cleaner, the aftercare is less, and there is the advantage of continuous negative pressure in the cavity. In two cases the Monaldi was subsequently converted into a relatively small cavernostomy. The disease was arrested eventually in one patient but only after lobectomy in the other.

CONTRAINDICATIONS

Our only contraindications have been (1) a history of profuse hemorrhage, (2) a free pleural space, (3) a cavity too small to enter with a trocar or inaccessible to safe and simple drainage (such as near the hilum), and (4) multiple cavitation so extensive that even successful drainage of one or two cavities would offer no reasonable hope of palliative relief.

The greatest hazard in drainage is a free pleural space. The failure to find a pocket with the exploratory needle is not proof of pleural symphysis. A blunt trocar will frequently separate pleural surfaces when no space can be found by a needle.

TECHNIQUE

Technique of drainage is divided into two parts: the first is the obliteration of the pleural space, and the second is the actual insertion of the trocar. Various methods of obliterating the space have been advocated, including the intrapleural instillation of the patient's own blood, sulfanilamide crystals, or talc. We now resect the intercostal muscles, usually together with a section of the first and second ribs, sprinkle sulfanilamide crystals on the endothoracic fascia, and pack the wound with gauze, close the skin, and then remove the pack in five days. Table II gives the number of cavities for which each method was used. In 13 instances early in the series no demonstrable pleural space was found with the exploratory needle and the trocar was successfully

TABLE II. METHODS OF OBLITERATING PLEURAL SPACE

1. No demonstrable pleural space (exploratory needle)	13
2. Injection of blood	4
3. Pack without rib removal	18
4. Rib removal with or without pack	63

In 2 patients too ill for pre-Monaldi packing or rib resection, a pneumothorax space was found and there was no further attempt to insert the trocar.

introduced. There were 4 instances in which cavity closure was obtained with pre-Monaldi rib resection alone. Two followed anterior resections and 2 posterior resections.

The amount of rib removed depends upon anticipated later treatment. If it is a purely palliative procedure with no hope of later thoracoplasty, extensive lengths of the upper two or three ribs are taken; however, the effect of extensive decostalization on pulmonary function must be considered. If thoracoplasty is deemed likely, we remove the first costal cartilage and a reasonable length of the first rib. If it is necessary to remove a bit of the second rib, this is taken lateral to the costal cartilage and as small a section as possible removed. This is a recent change in technique and has been necessitated by the relatively poor ultimate collapse if the anterior segments have regenerated before the thoracoplasty is performed. If a small segment of rib and costal cartilage has been left anteriorly, it is possible, at the time of the thoracoplasty, to remove the remaining anterior segments through a small separate anterior incision. This permits a better collapse. At the time of posterior thoracoplasty, rib resection is always terminated short of the point at which we are likely to break into the sinus tract. On two occasions the sinus tract was inadvertently entered. In neither instance did infection develop.

Insertion of the catheter under fluoroscopic control is advised. When possible, this has been performed two to three weeks after the packing. The location and depth of the cavity are ascertained with a 19 gauge aspirating needle, and when the cavity is entered, manometric readings are obtained. From Table III we see that in 47 cavities aspirated the pressures were positive; in 26, they were neutral; and in 9, they were negative.

TABLE III. MEAN CAVITY PRESSURE

Positive (plus 1½ to plus 18)	47
Neutral	26
Negative (minus 2½ to minus 6)	9

Occasionally, sputum will be obtained through the aspirating needle. When this occurs, it is proof that the needle is in the cavity. In one instance the cavity disappeared when air was withdrawn, and it was impossible to insert the trocar. This cavity subsequently reopened and was closed by thoracoplasty without further attempt at Monaldi drainage. There have been instances in which it was impossible to locate the cavity with a needle. In one such instance we were forced to conclude that the film had been misinterpreted and the cavity, if present, was much smaller than it seemed.

The Kupka modification of the Monaldi trocar is used. The safety flange is set at the proper depth, as determined by the aspirating needle. The needle is withdrawn and the trocar is inserted at the same point, in the same direction, and to the same depth. Manometric readings are again verified; the catheter

(No. 13 French) is inserted as far as it will go and the trocar withdrawn. The catheter is secured to the skin by a clove hitch of heavy silk fastened with adhesive. This holds the catheter without compressing the lumen. The position of the catheter is immediately checked by stereoscopic and lateral films.

Complications of insertion have been minor. The most common has been bleeding. This was of sufficient extent in 20 per cent to be noted on the record. In certain instances the bleeding had vitiated pressure readings or rendered it wise to discontinue the attempt temporarily. One hemorrhage, which was later fatal, occurred when the trocar was inserted despite the fact that brisk bleeding was encountered with the aspirating needle. There was one air embolism with temporary hemiplegia. Small pneumothoraces have on several occasions been a complication. If one is discovered with the aspirating needle, further attempt should be delayed. Pneumothoraces which are not found until after the insertion of the catheter are more troublesome. In only one instance was it necessary to aspirate air. One developed an empyema which proved fatal, as previously mentioned.

Table IV summarizes the complications of trocar insertions. Of the 100 cavities originally accepted for drainage, there was no attempt at trocar insertion in 9; in 7 of these the pre-Monaldi procedure resulted in such improvement that drainage was considered unnecessary, and in 2 others the attempt was not made because of the rapid deterioration in the patient's condition.

TABLE IV. TOTAL TROCAR INSERTIONS—113 IN 91 CAVITIES*

COMPLICATIONS DURING INSERTION		33 (29%)
1. Bleeding (1 led to fatality)		23 (20%)
2. Air embolus (nonfatal, temporary hemiplegia)		1
3. Pneumothorax pocket (1 led to fatality)		9 (8%)
(a) Pack without rib removal	2	
(b) No pre-Monaldi	3	
(c) Rib removal, no pack, but talc and sulfonamides	1	
(d) Rib removal, no pack	1	
(e) Present method	2	
(1) Resultant pyopneumothorax from traversing unobliterated fissure, and death (Case 81)		
(2) Pneumothorax without complications, tube not inserted		

*More than one attempt to introduce trocar:
2 patients had 4 attempts
3 patients had 3 attempts
11 patients had 2 attempts

POSTOPERATIVE CARE OF MONALDI DRAINAGE

Suction is not applied for twenty-four hours. Thereafter, a constant negative pressure of –20 to –30 cm. of water is maintained for twenty-four hours a day. For this purpose one of us (W.W.)[37] has devised a cabinet with a small electric motor, a constantly registering aneroid manometer, and a mercury safety valve which can be set for any level. Early in the series, pressures as low as –50 and –100 were used temporarily while the secretion was thick and tenacious, but it was felt that such highly negative pressures were not safe, as it was observed that the amount of sanguineous drainage was increased. If there is frank bleeding, suction is discontinued for one or two days. In two patients the occurrence of large hemorrhages made it advisable to abandon the procedure and withdraw the catheter. Monaldi[4-7] felt that an intermittent negative pressure is better than a constant one, in that it involves less risk of traumatizing the tissue. We prefer to maintain a constant negative level.

It is not uncommon for the sinus tract to become secondarily infected, and the amount of secretion may become profuse. Occasionally a chest wall abscess has developed around the catheter. This has been incised and drained. Streptomycin, when used either intramuscularly or by topical application, has cleared many of them promptly. Certain patients, however, have lost resistance to the tubercle bacillus to such an extent that the adjacent soft tissues have melted away and the disease has progressed rapidly. Otherwise, dressings are not a problem. Catheters are usually replaced monthly. At the time of the first change the catheter is usually shortened so that its tip barely reaches the posterior wall.

Blood or blood-tinged drainage was recorded in 45 per cent. It was usually a minor problem and cleared when suction was discontinued for a few days. In only two instances was it so profuse that the catheter was withdrawn and the method discontinued. Table V summarizes the late complications of the series.

TABLE V. COMPLICATIONS AFTER INSERTION

1. Bleeding through catheter (2 severe enough to force withdrawal of catheter)	37 (45%)
2. Chest wall abscess or sinus around tube	13 (16%)
3. Perforation of posterior cavity wall with resultant empyema; thoracoplasty and thoracotomy	1

EFFECT OF CAVITY DRAINAGE

As a general rule there was marked clinical improvement almost immediately. Some patients have a mild febrile course for the first few days, but thereafter most of them experienced a sense of well-being with the reduction in the size of the cavity. Probably the most significant factor in this improvement was the external drainage of the sputum, with the resultant decrease in cough and expectoration. With the relief of symptoms there tended to be an increase in appetite and a gain in weight. DesAutels and Hayes[18] published detailed studies on several of the early patients in this series upon whom follow-up study had been done up to one year.

Cavities tend to close rapidly when subjected to drainage. Table VI is an analysis of cavity behavior. Of the 82 into which a catheter was introduced, 40 were eventually closed without further therapy, 33, within six months. In 33 other instances the cavities became smaller, and in only 9 did they remain

Table VI. Effect of Monaldi on Cavity Drained

1. Cavity closure		
Within 1 month	6	
1 to 3 months	21	
3 to 6 months	6	
6 months or more	7	
		40 (49%)
2. Cavity smaller		33
3. Cavity unchanged or larger		9
Total drained		82

unchanged or become larger. In Case 2 the cavity could not be visualized at twenty-four hours.

Tubercle bacilli may disappear from the drainage in one month or less. In the presence of positive sputum and negative drainage another focus is suspected. An interesting observation has been that occasionally drainage has become negative while a cavity is still present. Table VII gives statistics on the disappearance of tubercle bacilli from sputum and drainage.

Table VII. Sputum and Drainage Statistics
(82 Cavities in 76 Patients)

	DRAINAGE (CAVITIES)	SPUTUM (PATIENTS)
1. Time of initial disappearance of tubercle bacilli by concentrated smear:		
1 month	5	9
2 months	15	6
3 months	6	5
4 months	6	4
5 months	2	1
6 months or more	6	9
	40*	34
2. Always positive	42	42
Total	82	76

*Of the 40 negative drainages the sputum remained positive in 18.

Extensive bacteriologic and pathologic studies have been performed by others on tuberculous cavities under various conditions. Steenken, D'Esopo, and Wolinsky[30] have reported their studies on excretion of streptomycin into tuberculous cavities. In 24 samples of intracavitary drainage in patients who were receiving streptomycin intramuscularly in dosages of 1.8 to 2 Gm. daily, they found an average concentration of 7.7 μg. per cubic centimeter, varying between 1 and 18 μg. The average concentration of the drug in the blood at the same time was 13.3.

RESULTS OF TREATMENT AND LATER PROCEDURES

One hundred cavities in 90 patients were originally accepted for treatment. In 7 instances the preliminary rib resection was followed by dramatic improvement. In 4 of these the cavities closed and in the other 3 they became so much smaller that drainage was thought unwise and thoracoplasty was performed in one. In 9 patients, repeated attempts were made to introduce the trocar, but were unsuccessful because of technical factors. These factors were usually the size or location of the cavity. Two patients were so ill that, following the preliminary stage, it was deemed unwise to proceed further. Catheters were actually inserted in 82 cavities in 76 patients. Four patients had 2 cavities drained and 1 patient had 3. Table VIII summarizes the entire group.

TABLE VIII. ACCEPTED FOR MONALDI

	PATIENTS (90)	CAVITIES (100)
1. Pre-Monaldi resulted in improvement so Monaldi not done (cavity closure in 4)		7
2. Catheter could not be introduced		9
3. Catheter not introduced because of deterioration in patient's condition		2
Total drainage	76*	82
Sex: 53 males, 37 females		
Age: Average, 33 (range from 19 to 61 years)		

*Four patients had 2 cavities drained, 1 patient had 3 cavities drained.

Forty cavities were closed by drainage and, of these, the catheters were removed or extruded from 7, in 6 patients, and the cavities have remained closed for periods ranging from eight months to four and one-half years (Table IX). In eleven others (Table X), the cavities reopened in from three weeks to fifty-nine months. Obviously there is no assurance that a cavity may not reopen long after the removal of the catheter. In certain instances in which this has occurred, it has been possible to re-establish drainage. It is logical to perform thoracoplasty, when possible, rather than to trust that the cavity will remain closed.

TABLE IX. CATHETER OUT—CAVITY REMAINED CLOSED
7 Cavities in 6 Patients

TIME ELAPSED SINCE REMOVAL OF CATHETER	NUMBER
8 months	1
3 years	3
4½ years (1 bilateral)	3

TABLE X. TUBE OUT AND CAVITY REOPENED IN 11 PATIENTS

INTERVAL BETWEEN REMOVAL OF CATHETER AND REOPENING OF CAVITY	NUMBER
Less than 3 months	2
3 months to 1 year	7
26 months	1
59 months	1
Total	11

When should a catheter be removed? We do not know. We have seen no ill effects from maintaining drainage indefinitely. One patient, Case 2, has had drainage continuously since August, 1940, because she refuses to allow the catheter to be removed, despite the fact that she has had a negative sputum and has been working full time in a sanatorium for several years. In general, in those patients for whom drainage is a palliative procedure and for whom no other therapy is available, we have left the catheters in indefinitely unless they were extruded.

For those patients who have been sufficiently improved by drainage to justify collapse or resection, we have not withdrawn the catheter until definitive surgery has been completed and, if possible, until the resected ribs have regenerated. Following catheter removal, most sinuses healed promptly, although streptomycin has occasionally been necessary. There have been instances of subsequent reopening after initial healing. This has usually been associated with reopening of the cavity.

The most heartening aspect of this method has been the number of patients who have been successfully prepared for further surgery. It has been noted that as one cavity becomes smaller, an adjacent cavity may become larger. For that reason we have felt that, when a cavity has been controlled by drainage, the improvement should be secured by thoracoplasty, if possible. Table XI shows that 30 patients have already had definitive surgery, and there is an excellent prospect that ultimately it may be possible for an additional 6. Thus 33 per cent of the entire group have already had the benefits of subsequent therapy. In only 76 patients, however, was drainage successfully carried out. There were 5 others[*] who obtained sufficient improvement from the pre-Monaldi so that it was thought wise to omit tube insertion. Of this total of 81 patients, 30, or 37 per cent, have already received more definitive therapy. In addition, there are 6 others who may yet have the advantage conferred by permanent collapse.

TABLE XI. SUBSEQUENT PROCEDURES

Thoracoplasty	25
Cavernostomy	1
Cavernostomy and lobectomy	1
Thoracoplasty and pneumonectomy or Pneumonectomy and thoracoplasty	3
Total who had more definitive procedure	30 (33% of entire series)
Thoracoplasty probable	6
Total who have had or may have more definitive procedure	36

Some of the thoracoplasties have not been as mechanically perfect as we should wish because of the regeneration of the anterior stumps before the posterior collapse could be completed, and also because, in view of limited respiratory reserves, we have not dared to make the collapse as extensive as the amount of the disease warranted.

Table XII is a summary of the present status of the 90 patients. Only 19 are regarded as "apparently well" and 31 are already dead. We anticipate that, with time, several of the remaining 40 will be classified as "apparently well." It should be remembered, too, that 11 of these patients were accepted

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[*] As seen in Table VIII, there were 7 patients with improvement following the pre-Monaldi procedure. In this group 2 patients had 2 cavities each, 1 drained, 1 not drained. Both of these 2 patients have already been tabulated in the total of 76 patients who had drainage. Accordingly, only 5 can be counted in the present tabulation.

TABLE XII. PRESENT STATUS

Apparently well:		
Monaldi alone	7	
With subsequent procedure	12	
		19
Still curing:		
Cavity closed	3	
Subsequent procedures	14	
Tube still in (To have thoracoplasty, 6)	12	
Tube out, cavity open	6	
Tube never inserted	5	
		40
Dead:		
After subsequent procedures	6	
All others	25	
		31
Total		90

for treatment in 1947 and there has not been a chance for the disease to be arrested.

While the mortality rate is already high, it is encouraging that so far 19 patients have apparently been reclaimed by this method. Many others who have not had arrest of their disease have had their lives prolonged with marked amelioration of their symptoms.

Of the 31 deaths, only 2 can be attributed to the treatment per se.

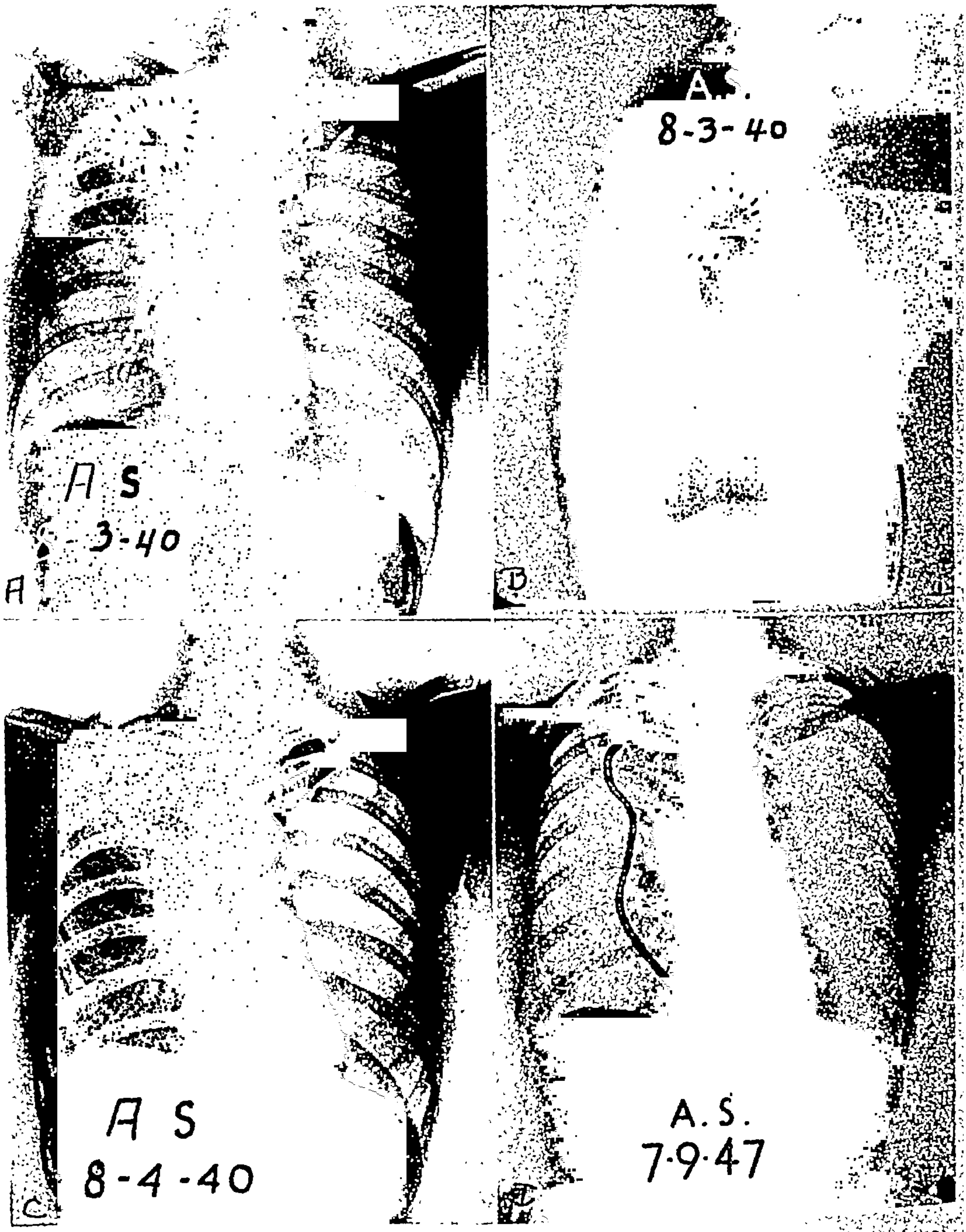
Tables XIII and XIV show the time and cause of death in all cases.

TABLE XIII. DEATHS AS RELATED TO TREATMENT

1. Tube never inserted		5
2. Early, within 1 month		
Hemorrhage	1	
Empyema	1	
		2
3. Late		
Less than 1 year	11	
1 to 2 years	6	
2 to 3 years	2	
3 to 4 years	3	
Over 4 years	2	
		24
Total		31 (34.4%)

TABLE XIV. CAUSES OF DEATH

Progression of disease	21
Postthoracoplasty, postpneumonectomy, 1	
Withstood thoracoplasty, 2	
Hemorrhage, either side	5
Empyema	1
Air embolism, late	1
Withstood thoracoplasty	
Pulmonary insufficiency	1
Postthoracoplasty	
Nontuberculous	2
Hypertension and nephritis, 1	
Suicide, postthoracoplasty, 1	
Total	31



Group I: Four cases are presented in which Monaldi alone was used (Cases 2, 18, 33, and 67).

Fig. 1 (Case 2).—A. S., woman, aged 27 years; indication: palliative. *A*, Bilateral disease, onset, 1929, left; pneumothorax, left, February, 1936; unexpandable lung, bronchial stenosis left main, tuberculous; cavity, right, note fluid level; sputum 60 c.c., Gaffky VII; temperature to 99.2° F. Pleural space, right, found to be obliterated. Respiratory function studies on July 5, 1940, revealed extremely low maximum minute ventilation. Catheter inserted Aug. 3, 1940. *B*, Lateral view showing posterior location of cavity, with catheter in place. *C*, Twenty-four hours later, cavity not visualized. *D*, Present status: Cavity not visualized since Aug. 4, 1940; sputum and drainage negative since 1941; working full time as medical secretary for several years. Patient refuses to have catheter removed, but we believe it should have been removed several years ago. She still applies suction at night. (Note: Clinical progress of this patient during the first year of drainage was published by DesAutels and Hayes.[illegible])

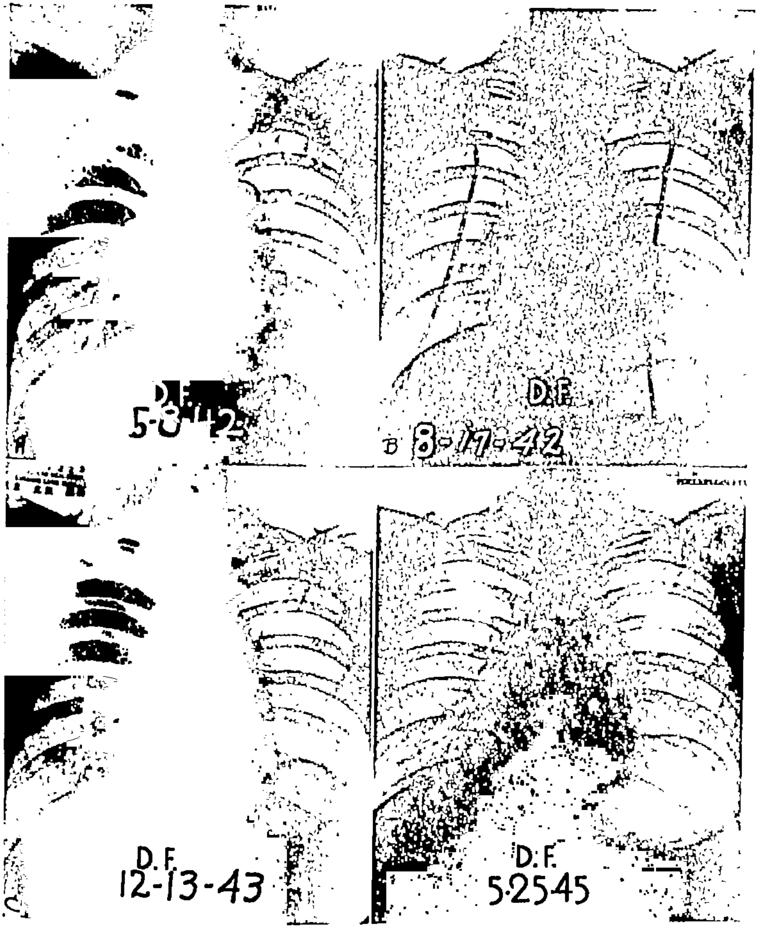


Fig. 2 (Case 18).—D. F., man aged 21 years; indication: palliative. *A*, Bilateral apical cavities; 25 c.c. Gaffky IV sputum; temperature 97 to 99° F.; bilateral pre-Monaldi packing, first interspace, without rib resection, Jan. 29, 1943; catheter inserted, right, May 8, 1942. *B*, Right cavity not visualized, drainage negative, June, 1942; catheter inserted, left, July 14, 1942; marked immediate decrease in size of cavity; possible development of new cavity medially. *C*, Drainage from both catheters negative after October, 1942; catheter, right, removed June, 1943; cavity left, not visualized after October, 1942; catheter, left, removed September, 1943. Phrenic, left, Nov. 3, 1943, for small adjacent cavity. *D*, Repeat phrenic, left, Jan. 5, 1945; patient discharged; both cavities have remained closed; sputum negative since Dec. 13, 1943. Letter from patient, March 31, 1945, stated "working on farm, feeling fine, have not had an x-ray for some time."

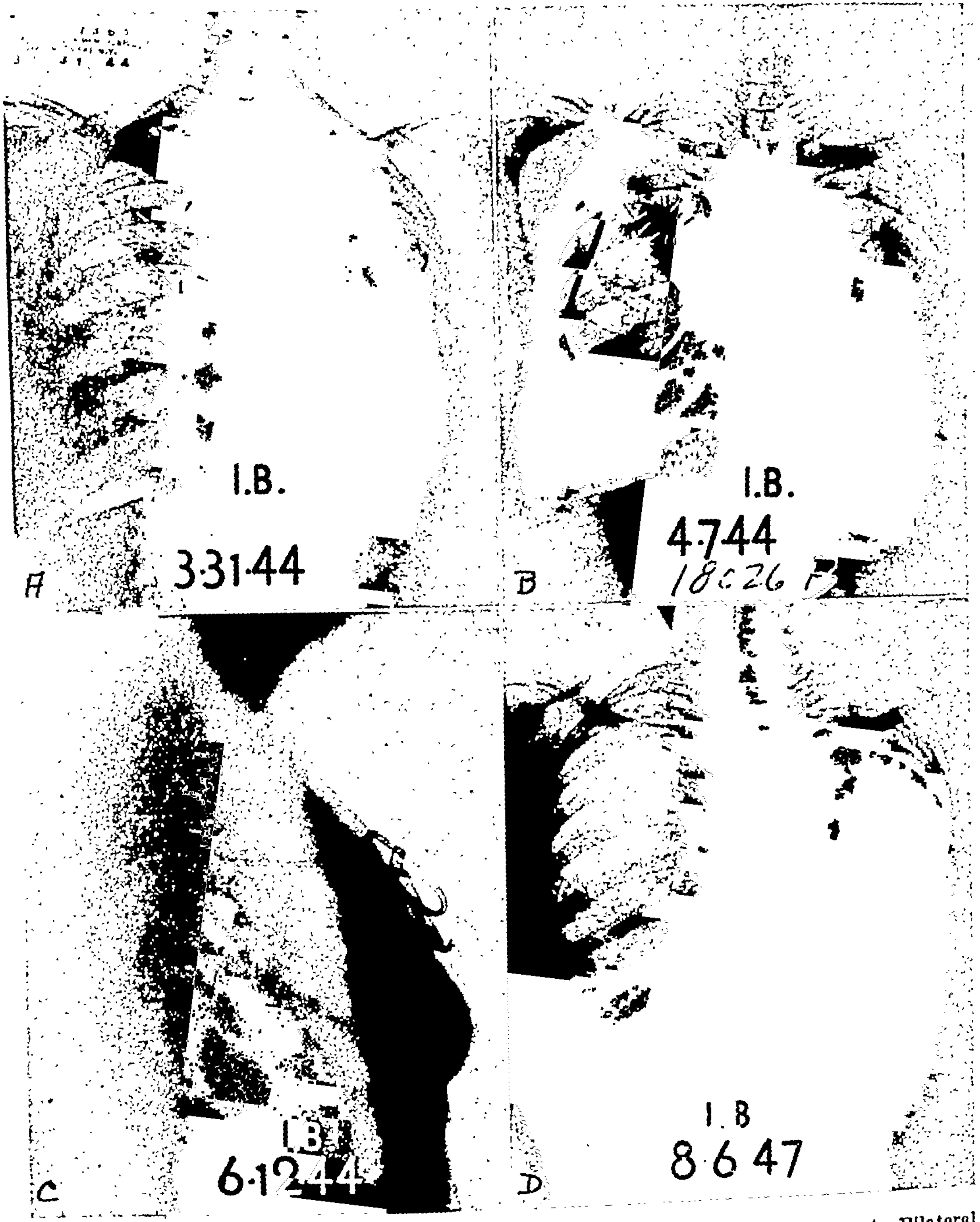


Fig. 3 (Case 33).—I. B., woman, aged 47 years; indication: palliative. *A*, Bilateral disease; pneumothorax, left, 1933 to 1938; lung failed to re-expand, pleural cavity filled with bloody serous fluid; sputum Gaffky VIII; temperature to 99.4° F.; cavity, right; pre-Monaldi rib resection, anterior end of first rib, Feb. 10, 1944. *B*, Catheter inserted, April 7, 1944; pressures +12, −6; first drainage Gaffky X. *C*, Lateral view; position strongly suggests cavity in apex of lower lobe; if true, catheter traversed fissure without incident. *D*, Cavity not visualized since June, 1944; drainage negative, July and August, positive Oct. 5, 1944; sputum negative Oct. 5, 1944; drainage negative Oct. 16, 1944; catheter removed November, 1944; present status: cavity closed, sputum negative; has remained well, doing own housework.

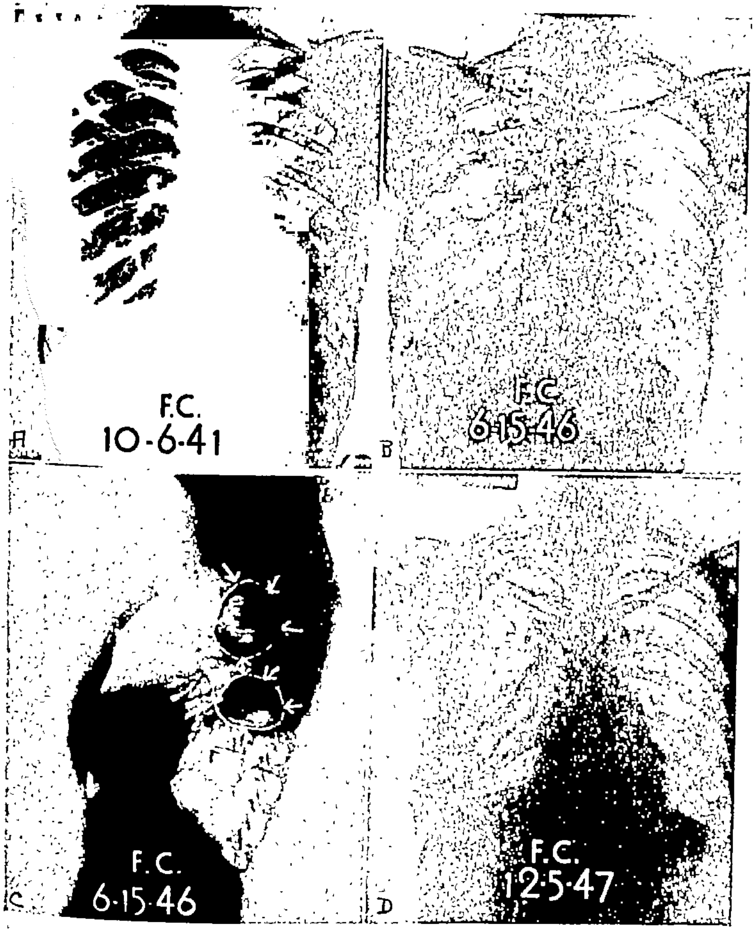
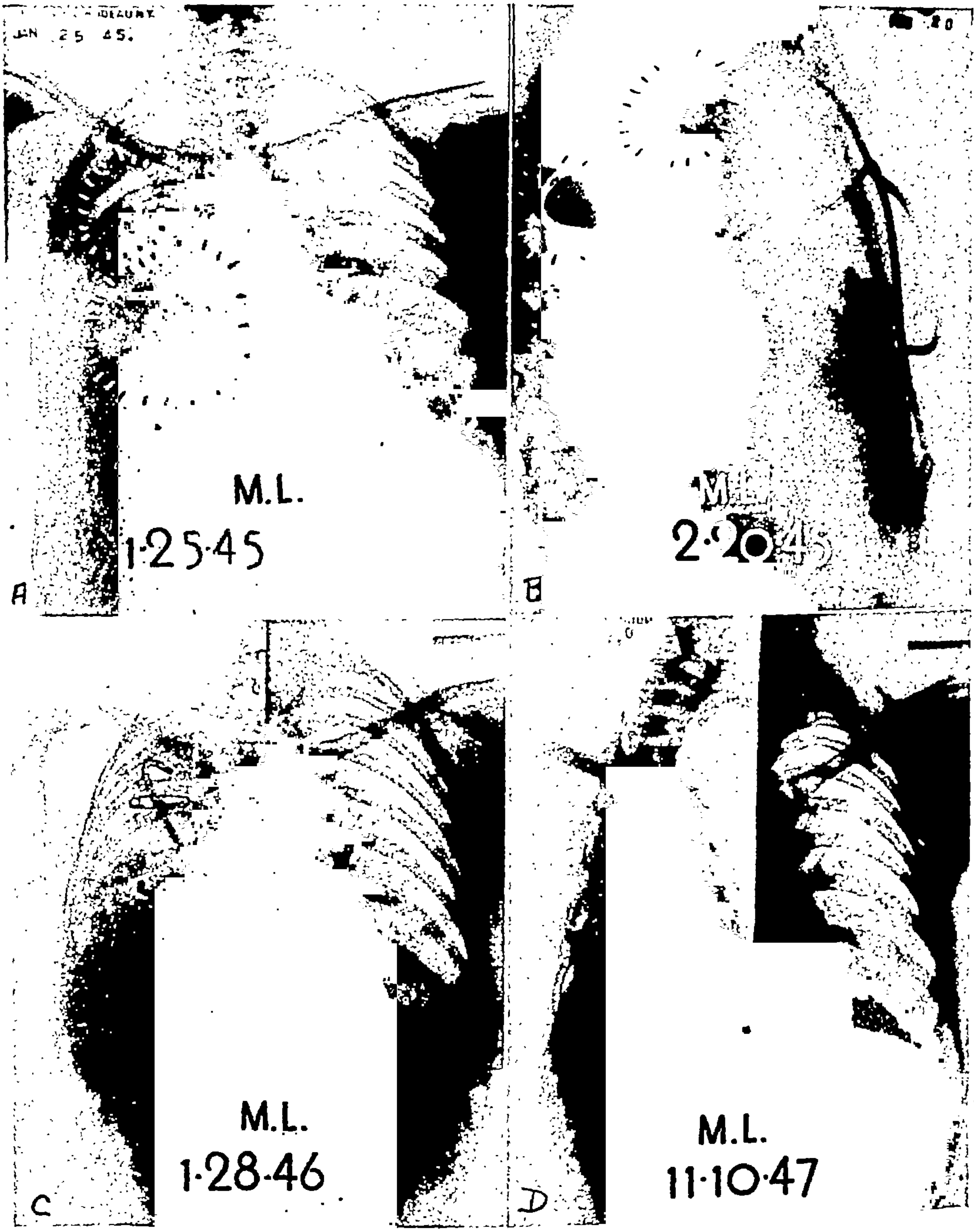


Fig. 4 (Case 67).—F. C., woman, aged 21 years; indication: palliative, pulmonary function not adequate for thoracoplasty or resection. *A*, Early film, at age of 16, five years before entering this series; extensive infiltration, left, with involvement of right. *B*, Had pneumothorax, left, for 8 months, 1941 to 1942; phreniclasis, left, Nov. 5, 1943; discharged from sanatorium Dec. 7, 1944; readmitted, February, 1946, with development of two large cavities, right; pneumothorax, right, instituted April 8, 1946, but abandoned because of increase in size of cavities. Note residual pneumothorax pocket and fluid levels in both cavities. Pneumonectomy considered but respiratory function studies, June 8, 1946, by Dr. George Wright, showed maximum minute ventilation of 70 liters and bronchospirometry revealed O_2 absorption 48 per cent on the right and 52 per cent on the left. Despite the cavities on the right, that side was carrying approximately the same respiratory load as the left because of extensive damage to the left by the disease of five years previously; patient, therefore, not suitable for either resection or thoracoplasty, right. *C*, Lateral film showing posterior location. This also shows why this lung is still functionally important. *D*, Pre-Monaldi resection the first to third anterior rib ends, on June 20, 1946; posterior pre-Monaldi resection of the fifth to eighth ribs on Aug. 6, 1946; disappearance of lower cavity by film of Aug. 26, 1946; catheter inserted into upper cavity, right, through anterior approach, Aug. 28, 1946; cavity apparently closed; catheter removed April 16, 1947. Patient in sanatorium Dec. 31, 1947, asymptomatic, with no cavity by planigrams, and sputum negative since January, 1947.



Group II: These two cases had drainage and thoracoplasty (Cases 45 and 66).

Fig. 5 (Case 45).—M. L., woman, aged 32 years; indication: palliative, possible prethoracoplasty. *A*, Acute bilateral disease; febrile; toxic; marked weight loss; giant cavity formation, right upper and lower. *B*, Resection of anterior ends of the first to fourth ribs on Jan. 20, 1945; insertion of two Monaldi catheters, right, Feb. 14, 1945; lateral view, note that lower catheter has traversed the oblique fissure without incident. *C*, Prethoracoplasty film showing marked reduction in size of cavities; patient's condition much improved. *D*, Thoracoplasty completed March 30, 1946; upper Monaldi catheter removed April, 1946; lower catheter removed Oct. 14, 1946; present status (nineteen months postthoracoplasty) markedly improved, small amount of positive sputum, residual basal cavity by planigram.

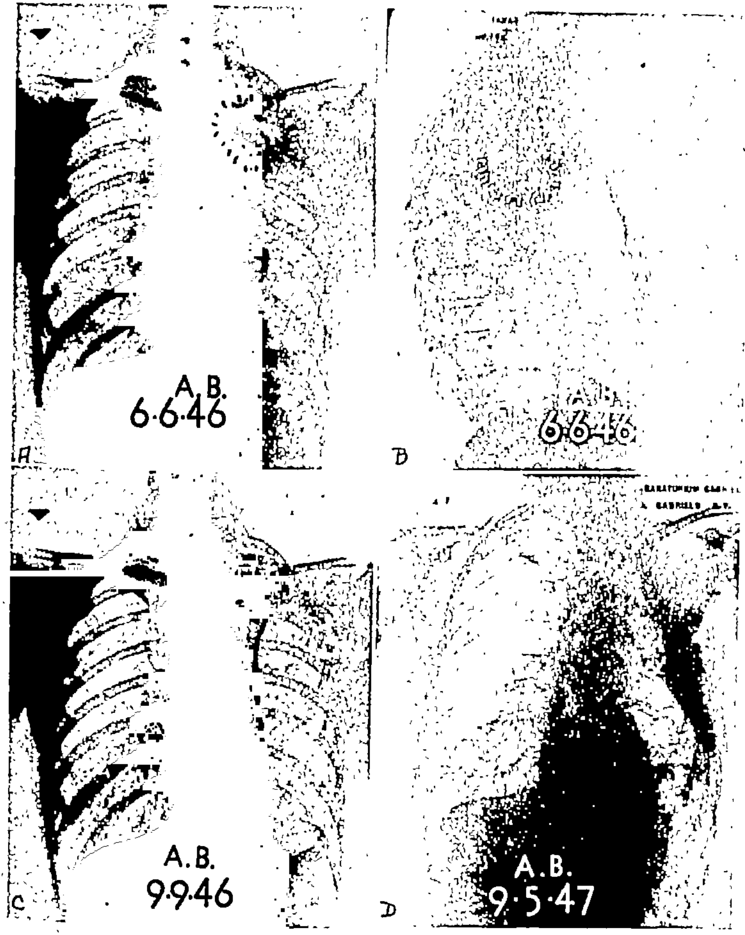
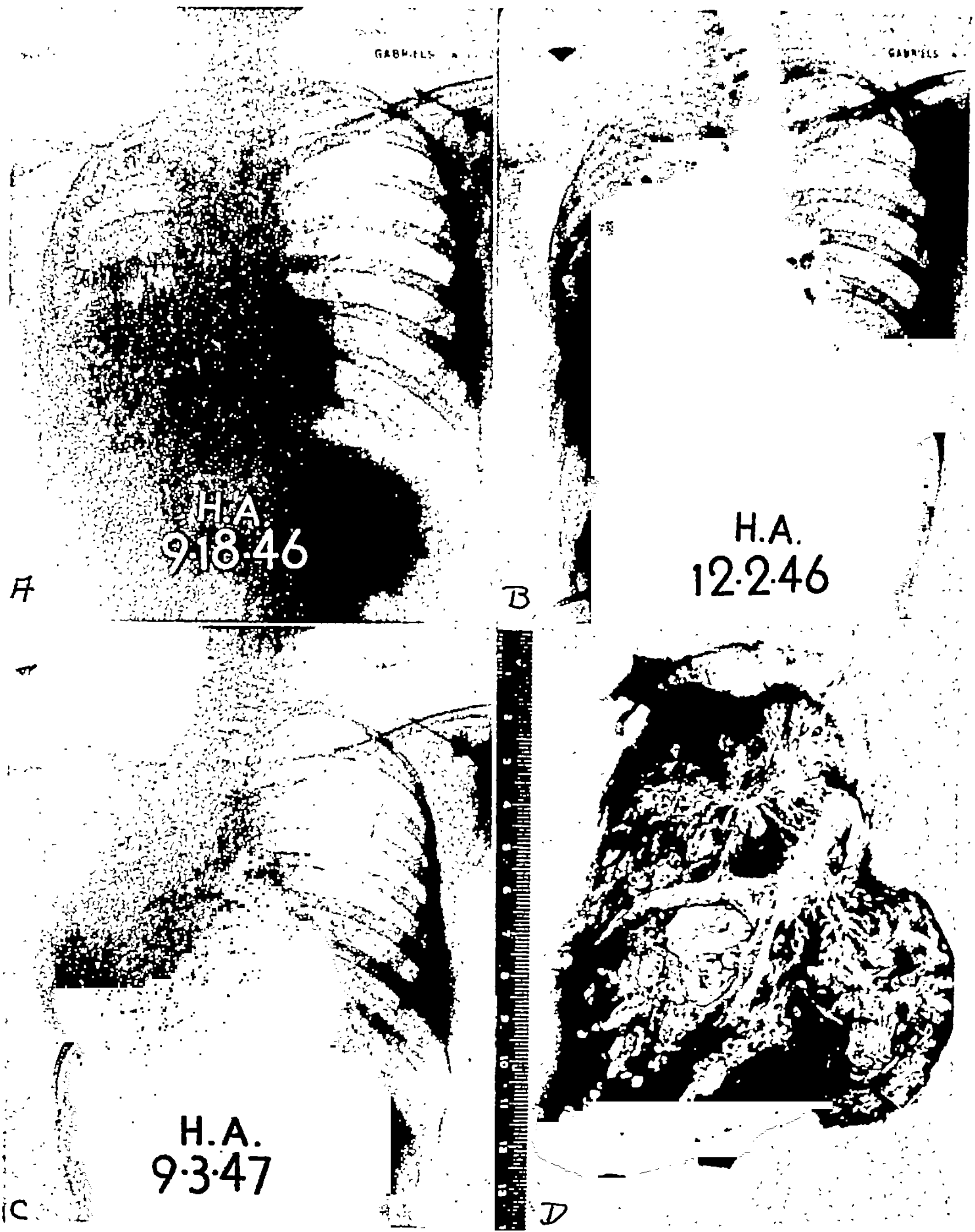
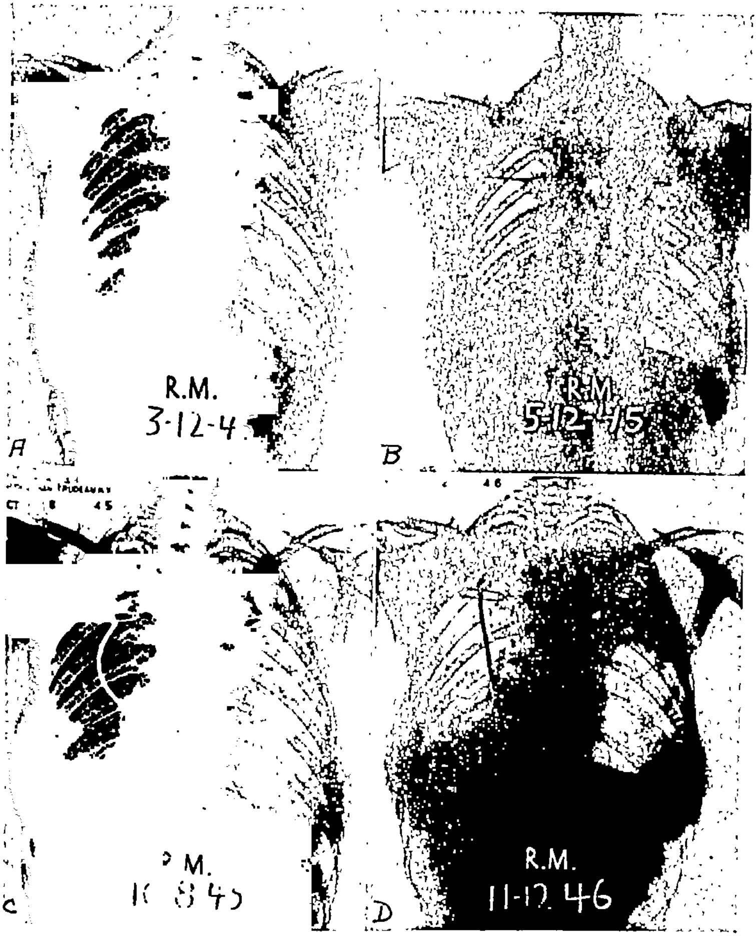


Fig. 6 (Case 66).—A. B., woman, aged 35 years; indication: palliative, possible pre-thoracoplasty. *A*, Bilateral tuberculosis with recent spreads; cavity, left, with fluid level; pre-Monaldi resection of anterior ends of the first to third ribs on May 16, 1946; catheter inserted June 6, 1946. *B*, Lateral view. *C*, Cavity closed; sputum and drainage negative. *D*, Seven-rib thoracoplasty completed, December, 1946; cavity closed and sputum negative as of Dec. 31, 1947.



Group III: One patient had Monaldi followed by resection and then thoracoplasty.

Fig. 7 (Case 71).—H. A., woman, aged 23 years; indication: palliative, possible prethoracoplasty. *A*, Acute disease, right, with two large cavities; patient raising 100 Gm. of Gaffky V sputum; temperature to 100° F. *B*, Posterior pre-Monaldi performed Sept. 19, 1946; with resection of segments of the seventh to tenth ribs; two posterior catheters inserted Oct. 16, 1946; marked reduction in size of cavities, symptomatic improvement, sputum Gaffky II, temperature not above 98.6° F. *C*, Lower catheter removed, January, 1947, cavity apparently closed at that time; pneumonectomy, right, through anterior incision, Feb. 27, 1947, and remaining catheter removed; thoracoplasty completed May 24, 1947. Present status: sputum negative; small residual draining sinus; insidious increase of disease, left. *D*, Section through resected lung. Note contracted scarred lung. Cavity in upper lobe not visualized; caseous focus in mid-lung apparently remnant of lower cavity.



Group IV: Two patients were followed from initial drainage to death (Cases 52 and 81).

Fig. 8 (Case 52).—R. M., woman, aged 31 years; indication: palliative. *A*, Bilateral disease, extensive cavity formation both lungs. In 1932 large cavities, right and left; artificial pneumothorax, right, 1932 to 1934; artificial pneumothorax, left, 1936 to 1941; began working, 1941; June, 1944, hemoptysis; development of cavity on right; later, two cavities, left; at present, sputum Gaffky IX, temperature to 100° F. *B*, Pre-Monaldi, bilateral, March 29, 1945; left, no free pleural space; right, anterior section of first rib removed; catheter inserted in left upper cavity on April 27, 1945, pressures +5, −3. *C*, Insertion of catheter on right, June 29, 1945, pressures +8, −3; drainage both sides, Gaffky II; no appreciable change in size of cavities. *D*, Insertion of second catheter on left, May 16, 1946; through large sinus, left anterior part of chest wall; bilateral improvement of cavity-bearing areas that were drained; development of new cavity (fourth) left base; sputum and drainage positive; death, Feb. 12, 1947, progressive tuberculosis.

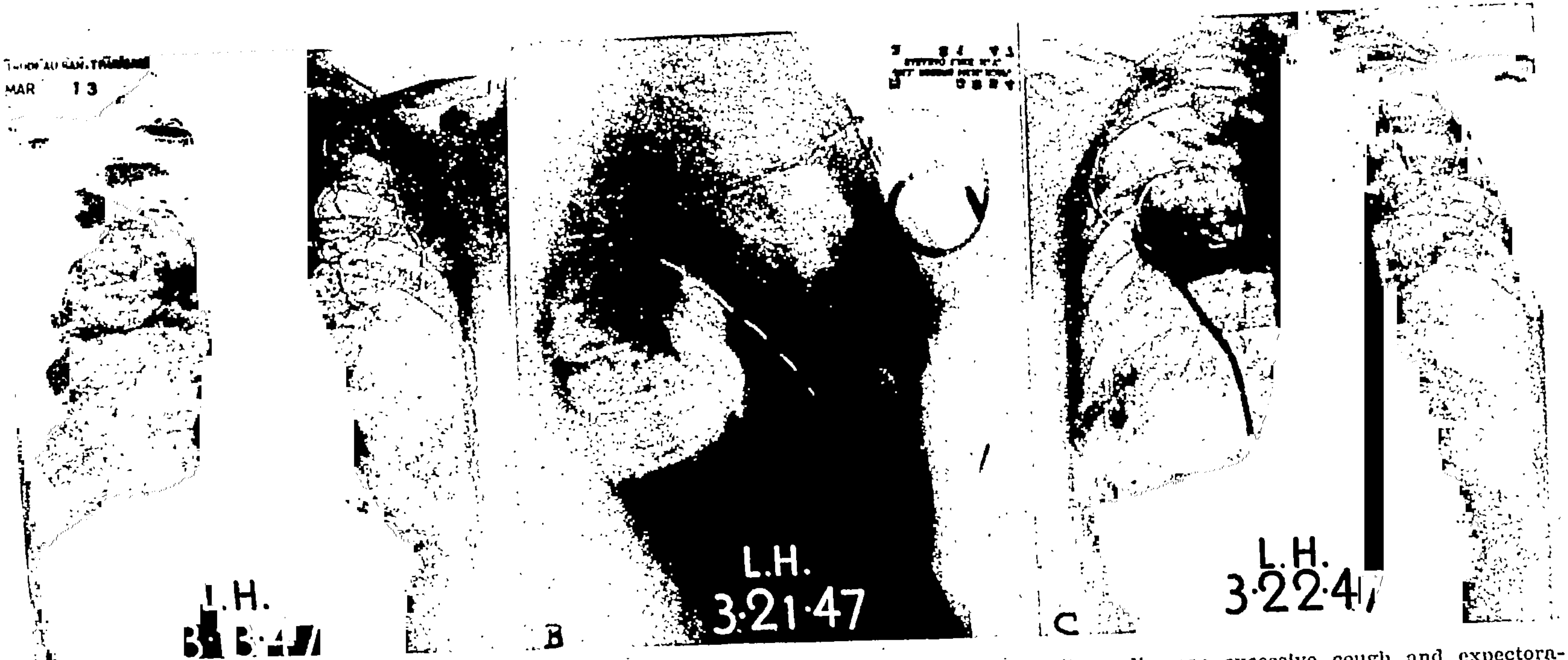


Fig. 9 (Case 81).—L. H., woman, aged 30 years; indication: palliative. *A*, Bilateral cavitary disease; excessive cough and expectoration. *B*, Lateral film, anterior rib resection Jan. 14, 1947, catheter inserted anteriorly. March 21, 1947, traversing oblique fissure. *C*, Pneumothorax resulting from trocar traversing oblique fissure. Patient developed fulminating pyopneumothorax; death on March 28, 1947. Autopsy revealed symphysis of pleurae at site of preliminary packing but no obliteration of the interlobar fissure. This represents an error in judgment. There was almost no possibility of controlling all of the cavities and the hazard of traversing a fissure was unjustified.

Figs. 1 to 9 show, by a series of films and accompanying legends, the progress of 9 representative patients who have been subjected to intracavitary drainage.

SUMMARY

1. Intracavitary drainage has been used as a salvage procedure, both as a palliative in otherwise hopeless cases and as a method of preparing certain patients for collapse therapy. Without this help most of them could not have had their final surgery.

2. The method has been described, detailed tables presented, and several representative series of films shown.

The cooperation of the following physicians and sanatoriums has made this study possible: Dr. John N. Hayes, Dr. J. Woods Price, Dr. Henry W. Leetch, Dr. Francis B. Trudeau, Dr. Daniel M. Brumfiel, Sanatorium Gabriels, Will Rogers Memorial Hospital, Trudeau Sanatorium, Northwoods Sanatorium, and Broadacres Sanatorium of Utica.

REFERENCES

1. Head, J. R.: Intracavitary (Monaldi) Suction, J. THORACIC SURG. 15: 153-161, 1946.
2. Woodruff, Warriner: Discussion of Symposium on Tension Cavities, J. THORACIC SURG. 15: 156-157, 1946.
3. Monaldi, V.: Tentativo di aspirazione endocavitaria nelle caverne tubercolari del polmone, Lotta contro tuberc. Anno IX, No. 10, 1938—XVI, pp. 3-4, 1938.
4. Monaldi, V.: *Endocavitary Aspiration: Its Practical Applications*, Tubercle 28: 223-228, 1947.
5. Monaldi, V.: L'aspirazione endocavitaria nella cura delle caverne tubercolari del polmone, Sett. med. 27: 231-240, 1939.
6. Monaldi, V.: Sul meccanismo della delimitazione del processo tubercolare del polmone (Basi-teoriche del procedimento di aspirazione endocavitaria), Ann. Ist. Carlo Forlanini 3: 201, 1939.
7. Monaldi, V.: Treatment of Tuberculous Pulmonary Cavities by Suction Drainage, Ztschr. f. Tuberk. 82: 273, 1939.
8. Monaldi, V., Bottari, G., and Babolini, G.: Alcune osservazione sulla condotta del procedimento di aspirazione endocavitaria, Ann. Ist. Carlo Forlanini 3: 374, 1939.
9. Bottari, G., and Babolini, G.: Strumentario e tecnica per l'attuazione pratica del procedimento di aspirazione endocavitaria di Monaldi, Ann. Ist. Carlo Forlanini 3: 365, 1939.
10. Coryllos, P. N.: The Mechanics and Biology of Tuberculous Cavities, Am. Rev. Tuberc. 33: 639-660, 1936.
11. Coryllos, P. N., and Ornstein, G. G.: Giant Tuberculous Cavities of the Lung, J. THORACIC SURG. 8: 10-54, 1938.
12. Eloesser, L.: Blocked Cavities in Pulmonary Tuberculosis, J. THORACIC SURG. 7: 1-22, 1937.
13. Davidson, Louis R.: Modified Instruments and Technique in the "Monaldi Procedure," Quart. Bull. Sea View Hosp. 5: 385-400, 1940.
14. Dolley, Frank S.: Transpleural Aspiration of Tuberculous Cavities (Monaldi), (Editorial), Am. Rev. Tuberc. 41: 661-663, 1940.
15. Wolf, J. E.: Monaldi's Suction Drainage of Pulmonary Cavities, Schweiz. med. Wchnschr. 70: 600, 1940.
16. Passalacqua, H. A., and Dunan, M. O.: Suction Drainage of Tuberculous Cavities of Lung, Prensa med. argent. 27: 1491, 1940.
17. Kupka, Edward, and Wells, Ruth: Technique of Cavity Aspiration (Monaldi), Am. Rev. Tuberc. 42: 401-411, 1940.
18. Kupka, Edward, and Bennett, Edwin S.: Monaldi's Suction Aspiration of Tuberculous Cavities, Am. Rev. Tuberc. 42: 614-621, 1940.
19. Kupka, Edward, and Wagner, William: Intentional Obliteration of Pleural Space by Blood, Am. Rev. Tuberc. 43: 291-294, 1941.
20. Kupka, Edward: The Monaldi Procedure—a Progress Note, Dis. of Chest 7: 373-377, 1941.

21. Roche, Hiliary: The Treatment of Tuberculous Lung Cavities by Closed Suction Drainage—Monaldi's Method, Tubercle 22: 1-21, 1941.
22. Roche, Hiliary: The Tuberculous Lung Cavity and Monaldi's Closed Suction Drainage, M. J. Australia 2: 307-310, 1945.
23. Cussen, J. V.: Direct Drainage of Lung Cavities in Pulmonary Tuberculosis, Brit. M. J. 1: 115-117, 1941.
24. Joannette, A.: Drainage of Tuberculous Cavities by Aspiration (Monaldi Method), Canad. M. A. J. 44: 46-48, 1941.
25. Goldman, Alfred, Brunn, H., and Ackerman, L.: Tuberculous Cavities—Observations on Transpleural Decompression, Am. Rev. Tuberc. 43: 151-183, 1941.
26. Salkin, David, Cadden, A. V., and McIndoe, R. B.: The Blocked Pulmonary Cavity, Am. Rev. Tuberc. 34: 634-648, 1936.
27. Schuberth, A.: Treatment of Cavernous Pulmonary Tuberculosis With Suction Drainage of Cavities, Schweiz. med. Wchnschr. 71: 1412-1416, 1941.
28. Sellors, T. H.: Closed Suction Drainage of Tuberculous Cavities, Tubercle 23: 239-255, 1942.
29. Cronin, R. C.: A Multiple Pumping System for Cases of Cavity Drainage, Tubercle 24: 184-187, 1943.
30. Eloesser, Leo, Rogers, W. L., and Shipman, S. L.: Treatment of Insufflated Cavities, Am. Rev. Tuberc. 51: 7-17, 1945.
31. Maier, Herbert C.: Surgical Treatment of Tension Cavities in Pulmonary Tuberculosis, Am. Rev. Tuberc. 51: 1-6, 1945.
32. Vineberg, A. M., and Kunstler, W. E.: The Determination and Treatment of Pressure Cavities in Pulmonary Tuberculosis, Surg., Gynec. & Obst. 78: 245-274, 1944.
33. Alexander, John: Discussion of Symposium on Tension Cavities, J. THORACIC SURG. 15: 156-157, 1946.
34. O'Brien, E. J.: Discussion.[33]
35. Eloesser, L.: Discussion.[33]
36. Welles, E. S., and Gordon, Joseph: Preliminary Anterior Chondrocostectomy Combined With Closed Cavity Drainage and Posterior Thoracoplasty, J. THORACIC SURG. 17: 555-565, 1948.
37. Woodruff, Warriner: A Suction Cabinet for Use in Cavity Aspiration (Monaldi), Am. Rev. Tuberc. 52: 502-504, 1945.
38. DesAutels, E., and Hayes, John N.: Transpleural Intracavitary Aspiration (Monaldi), Am. Rev. Tuberc. 45: 484-498, 1942.
39. Steenken, William, Jr., D'Esopo, Nicholas D., and Wolinsky, Emanuel: Excretion of Streptomycin Into Tuberculous Cavities, the Pleural Space and the Tracheobronchial Tree, Am. Rev. Tuberc. 51: 403-404, 1947.

DISCUSSION ON "INTRACAVITARY SUCTION (MONALDI) IN THE TREATMENT OF EMPHYSEMATOUS BULLAE AND BLEBS" BY DR. JEROME R. HEAD AND DR. EDWARD E. AVERY,* AND "REVIEW OF SEVEN YEARS' EXPERIENCE WITH INTRACAVITY (MONALDI) DRAINAGE OF TUBERCULOUS CAVITIES" BY DR. WARRINER WOODRUFF, DR. WINFIELD O. KELLY, AND DR. ALLAN STRANAHAN

DR. PAUL C. SAMSON, Oakland.—The differentiation between so-called blebs and intrapleural pulmonary cysts is a very important one. There is too much confusion in the literature between these two entirely different pathologic entities. I would question, however, whether one should split hairs, as it were, in trying to differentiate blebs and bullae; it seems to me that the pathology is so similar that there is little reason for trying to distinguish between them.

In so far as treatment is concerned, the authors have agreed that Monaldi drainage is, for them, the treatment of choice. I cannot argue too strenuously with that because I have never tried the Monaldi procedure, but I can with some assurance speak of the surgical treatment of the lesions, and I believe that our results are good enough for surgery to be considered not infrequently in treating these conditions.

(Slides.) In the first place, the pathology is such that I am unable to tell how Monaldi drainage can completely relieve the condition. This slide shows multiple cystic blebs laid open in the upper lobe. They were not visualized in the x-ray examination. There are interlacing strands of alveolar septa and multiple fistulas in the base. These are not tension cysts; when the lung is removed from the body they all collapse.

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*See page 761 for article by Head and Avery.

Dr. Dugan and I have performed operations on 7 individuals; one was a bilateral lobectomy and is the only case in which total lobectomy was done.

In the other patients, excisional surgery was performed by clamping across normal lung beneath the base of the cyst, excising the cyst and the subjacent battered parenchyma. There was minimal sacrifice of normal lung. In one patient, 5 cysts were removed, varying in diameter from 8 cm. to 3 cm. Such an experience speaks for a surgical, rather than a suctional approach in many instances. We have had immediate re-expansion of the lung in all cases. Of course, many of these patients may appear to be in poor physical condition prior to operation, because of diminished vital capacity. This situation is remedied immediately, however, as soon as the thorax is open and the giant bleb deflated.

DR. W. E. BURNETT, Philadelphia.—I would like to commend Dr. Head and Dr. Avery on this very ingenious way of approaching these most difficult problems. I wish I had known about this sooner, but in the past we have used the surgical approach, as Dr. Samson has done. It is noteworthy that in these patients, as has been called to our attention this morning, many times the cysts are not demonstrable; I am using the term cyst, meaning blebs and bullae. A great many have not shown identifiable allergy, although a good many have been improved by bronchial relaxants and aerosol of penicillin. One patient that seemed too diffuse for operation has greatly improved clinically. Dr. Rosemond and I have operated on approximately 11 of these patients, with great relief up to three years in all but 2.

(Slides.) As you see, this patient had an extremely large cyst. It was resected, and it was very simple to remove this large cyst without removing any significant amount of lung. In another patient, we have taken out several cysts from the right side, including parts of each lobe, without doing a lobectomy; we reserve that for intrapulmonary cysts. As long as the lesion can be recognized, it certainly seems wise to remove it, despite the fact that there is decrease in pulmonary function. After operation the function rapidly improves. The compressed lung of one man, who had had a similar large cyst in the chest for five years, was seen to re-expand rapidly at operation when the bulla was removed and positive pressure was applied by the anesthetist.

We have comparative studies on the more recent cases, and postoperative studies on even the earlier cases. One man had a reserve of 43 pr cent before operation, 23 liters maximum breathing capacity, with 70 per cent oxygen utilization on the right and 21 per cent on the left. Postoperatively, the 43 per cent reserve was increased to 70 per cent, with the distribution equal between the two lungs. We think this is an effective method of dealing with large blebs or bullae, but the lesion must be localized, not diffuse, and extremely ill patients may present too much risk. The simpler, although more prolonged, method used by Dr. Head and Dr. Avery offers great value, particularly since the disease is usually a progressive one, and therefore, any surgery which does not remove the cause is only palliative, although a great deal of relief can be afforded in properly chosen cases. At any rate, great effort should be made to find and eradicate etiological factors in combination with either method.

DR. ARTHUR VINEBERG, Montreal.—The subject of large tension cavities should be reviewed from a different point of view. The procedure of in tracavitary drainage is a useful one. It should be employed as a preliminary procedure in the treatment of all tension cavities. The practice of treating moribund, or nearly moribund, cases by intracavitary drainage throws discredit on the procedure. The so-called salvage cases do badly no matter how they are treated.

In reviewing a group of thoracoplasty results in Montreal, we have not been pleased with the number of persistently positive cases. The thoracoplasties have been performed by many different surgeons in our district; usually the collapse appears to be excellent.

pneumothorax, thoracoplasty, and other collapse therapy procedures. Our restriction of Monaldi drainage to patients presenting unsuitable indications for other forms of treatment when used alone probably accounts for our relatively poor results, as compared with others' series, in patients with a better prognosis.

DR. J. D. MURPHY, Oteen.—I wish to make two brief points. In a series of 15 patients we have used Oxycel gauze* to cause a fusion of the pleurae. In fusion of the pleurae previous to the Monaldi, a site is selected nearest the peripheral point of the cavity, and under general anesthesia an intercostal incision is made down to the endothoracic fasical plane. The parietal pleura is dissected with finger and gauze dissection over an area sufficiently large to insert a 4 by 4 square of Oxycel. The wound is then tightly closed. After ten days to two weeks we have found the pleurae fused and have inserted a catheter through a trocar in the usual manner. We have occasionally resected a piece of rib in making this dissection. This modification saves the patient considerable time in that one stage of operation is avoided, that of removal of a gauze pack and subsequent delay of insertion of the catheter.

These 15 patients have been a part of a series of attempted salvage cases. The patients have had extensive bilateral disease with a large cavity in one apex. The bilateral disease was so advanced as to preclude consideration for major surgery. Following the insertion of the Monaldi catheter and initiation of pneumoperitoneum therapy, there has been a distinct improvement in this group and we have already performed a thoracoplasty with conversion of sputum in 5 of them. The thoracoplasty was preceded by an average of six months' pneumoperitoneum therapy with catheter in place.

DR. EDWIN J. GRACE, Brooklyn.—The big problem of the tension cavity I do not think can be solved by using detergent antibiotic therapy as an aerosol. In fact, this patient became progressively worse by the inhalation method, and it was found unsatisfactory. (Slides.) As you can see the tension cavity became enormously enlarged as a result of using the aerosol method. While waiting to produce a chemical obliterating pleuritis over the posterior aspect of the tension cavity, in order to put the detergent antibiotic synergistic solvent directly into the cavity, the patient left Brooklyn to see Dr. Overholt, who performed a lobectomy. A recent follow-up study eight months after the operation provided us with the information that the patient is doing very well.

DR. HEAD.—My participation in this work has been very happy. I suggested that it might work, and Dr. Avery has made it work. He has been responsible for taking care of these patients and for the surgery done upon them.

Dr. Samson said that it was not important to distinguish between bullae, blebs, and cysts. I feel that it is important. Progress in medicine and surgery depends very much upon increasingly fine distinctions between disease entities. Lack of discrimination and loose and inexact use of terms always create confusion. Bullae, blebs, and cysts are distinct and different conditions, differing in etiology and pathology and in the indications for treatment. It is very important that we do differentiate between them. In doing so it is interesting to remember that it was William Snow Miller, to whom we are all indebted in so many ways, who described the important etiological and anatomical differences between bullae and blebs.

Dr. Graham has asked whether, once deflated, these blebs remain so, or whether, as in the case with tuberculous cavities, they re-open. So far all of them have remained closed.

DR. WOODRUFF.—I just want to comment on the discussion of Dr. Vineberg. I think this procedure definitely has a place in the treatment of large tension cavities. We are no longer performing thoracoplasties over large cavities without previous decompression. I should like to show two slides which illustrate why we have modified our prethoracoplasty procedure.

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*Manufactured by Parke, Davis & Company, Detroit, Mich.

(Slide.) This slide shows the condition before Monaldi drainage: There is a cavity on one side and a partially unexpanded lung on the other. Moderately long segments of the first and second ribs were removed before the drainage. When the thoracoplasty was performed seven months later, there had been so much regeneration of the anterior stumps that it was impossible to get a complete collapse. (Slide.) This slide shows the thoracoplasty which, although adequate in this instance, is technically poor due to the long regenerated struts of the anterior rib ends.

Because of several similar results, we have modified our technique in those instances in which we anticipate subsequent thoracoplasty. We now take a fair length of the first rib and its cartilage but a very short segment of the second rib and no cartilage. Following the first or second posterior stage of the thoracoplasty, we then remove the second cartilage. This procedure aids in mobilization of the anterior chest wall, and its use has resulted in better collapse.

COARCTATION OF THE AORTA

REPORT OF SIX CASES WITH OPERATION

H. BRODIE STEPHENS, M.D., AND ORVILLE F. GRIMES, M.D. (BY INVITATION)
SAN FRANCISCO, CALIF.

COARCTATION of the aorta is not a rare congenital anomaly. It occurred as the primary lesion in 85 of Abbot's 1,000 cases of congenital heart disease, and as a complicating anomaly in 93 others. Two anatomic types of coarctation, infantile and adult, are recognized. The infantile type is usually accompanied by other more severe congenital defects and in most instances death occurs in infancy. It is characterized by a narrowing of the aorta between the origin of the left subclavian artery and the insertion of the ductus arteriosus. This condition normally exists in the fetus, where the ductus arteriosus carries blood into the descending aorta while the aorta proximal to the ductus is narrowed. In the so-called adult type, usually seen in adults and in children past infancy, there is a sharp constriction or obliteration of the descending aorta at or near the site of insertion of the ductus. The most popular explanation of the etiology of this type postulates that the obliterating action of the ductus, which occurs soon after birth, affects the neighboring portion of the aorta. This interpretation leaves unexplained the fact that in almost 10 per cent of cases of coarctation the ductus is patent.

Hypoplasia of the aorta is a frequent complicating congenital defect. The condition of the aorta proximal to the site of coarctation is now of more than theoretical importance in view of the development of a surgical attack on this defect. While the proximal aorta is hypoplastic in about 10 per cent of cases, in at least 50 per cent there is dilatation of the proximal aorta. This is probably due to the increased pressure in that segment and possibly to an inherent weakness of the aortic media. When the proximal aorta is greatly dilated and weak, rupture may occur. This catastrophe occurred in 38 of Abbot's cases.

Coarctation definitely shortens the life of the individual, although symptoms may not appear until the patient is well into adulthood. Cardiac decompensation is the leading cause of death and once this appears, the patient's course is speedily downhill. Spontaneous rupture of the aorta, cerebral accidents, and mycotic endarteritis are also frequent causes of death.

For reasons that are only partially known, in patients with coarctation the vascular system proximal to the coarctation is subjected to various stresses which render these tissues liable to inflammatory or degenerative changes. This is of great significance, not only as an added indication for early surgical intervention, but also because it indicates the difficulties attendant upon such intervention. Aortic tissue that has been subjected to hypertension for decades is not the ideal tissue to hold sutures while being pounded by the blood stream.

From the Department of Thoracic Surgery, University of California Medical School.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

Consequently these patients should be operated upon early in life before irreversible changes in the vascular system have developed.

The central theme of this paper is a review of the case histories and operations of six patients in whom coarctation of the aorta was verified.* It is our hope that the presentation of this group of cases will provide informative data to a subject still young in the annals of operative endeavor.

CASE REPORTS

CASE 1.—W. S., a 16-year-old boy, entered the University of California Hospital Oct. 12, 1947. After a bout of bronchopneumonia at the age of 7 year, he had recurrent attacks of asthma occasionally requiring medical aid. He complained of bilateral calf pain, noted most often while at rest following exercise. Suboccipital, supraorbital, and bitemporal headaches usually followed severe exercise so that he had long since learned to limit his activity. He was aware of coldness in the lower half of his body while the upper torso and arms might be perspiring from the effects of environmental temperature. There was no dyspnea, chest pain, palpitation, cyanosis, or edema of the lower extremities.

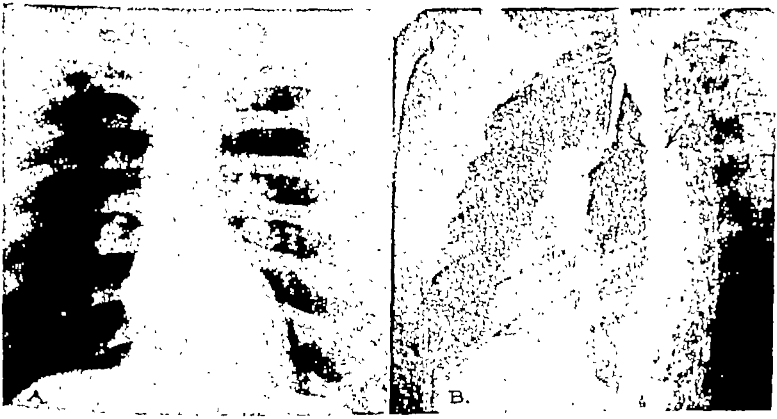

Fig. 1 (Case 1).—The heart was not enlarged and its contours were normal (*A*). Retrograde carotid arteriography demonstrated that the transverse aortic arch was hypoplastic. The coarctation (*arrow*) was located immediately distal to the point of origin of the left subclavian artery. The latter was at least twice normal size (*B*).

The heart was not enlarged and its rhythm was regular. A systolic murmur was heard posteriorly at the level of the third to fifth ribs in the paravertebral line. The arterial pulsations in the upper extremities were normal in quality. The peripheral tension in the right arm was 180/105, and in the left 160/105 mm. Hg. The abdominal aortic and femoral pulsations were barely discernible and those below the femoral level were not palpable. No blood pressure readings could be obtained in either lower extremity.

The red blood cell count was 6.03 million per cubic millimeter, and each 100 c.c. of blood contained 13.0 Gm. of hemoglobin. Urinalysis showed no abnormal findings, and the renal function as measured by phenolsulfonphthalein excretion was 59 per cent. The blood volume was within the range of normal. High voltage in the precordial leads was the only abnormality noted on the electrocardiograph, suggesting a minor degree of left ventricular hypertrophy. A roentgen film of the chest showed notching of the ribs. The retrograde carotid arteriogram demonstrated hypoplasia of the transverse arch and a definite coarctation at the junction of the aortic arch and the descending aorta. The left subclavian artery was at least twice normal size (Fig. 1).

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*Since this report there have been 9 additional resections for coarctation of the aorta with one death. The fatality occurred in a 35-year-old man in whom the coarctation had been excised and restoration of the lumen re-established by end-to-end union. Death was due to hemorrhage at the suture line on the tenth postoperative day. The results in the other 8 patients have been satisfactory.

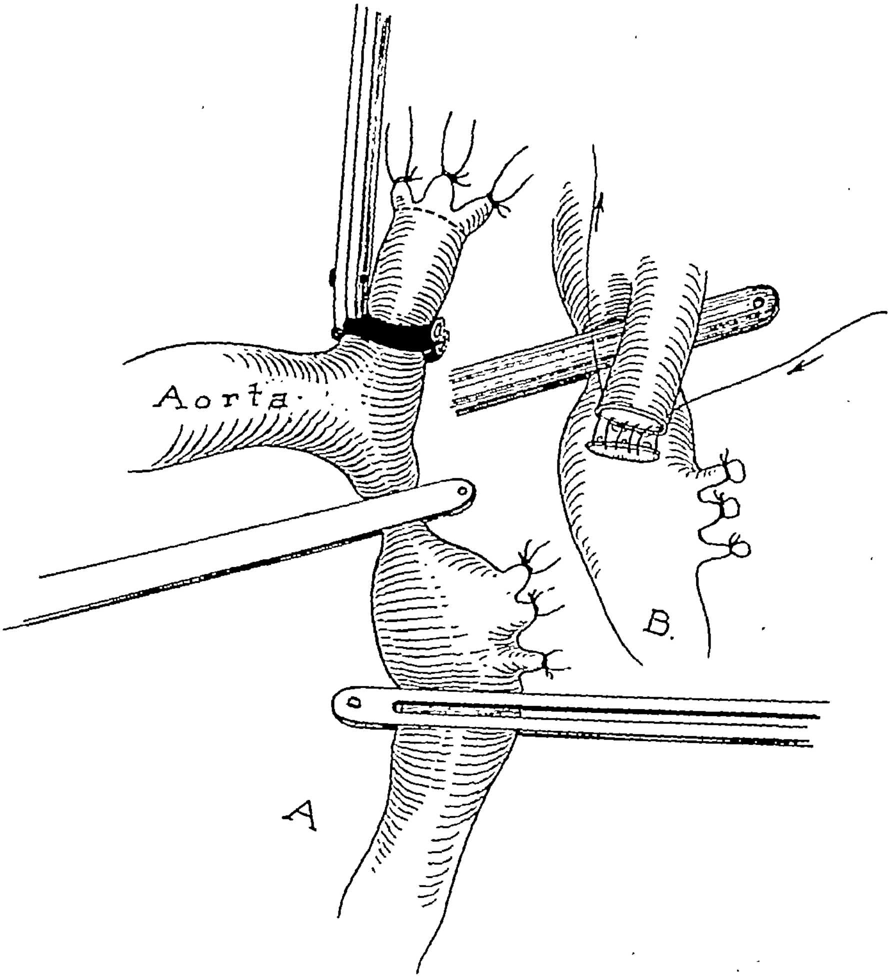

Fig. 2 (Case 1).—Several enlarged intercostal arteries were divided in order to mobilize the aorta. The subclavian artery was occluded by a Blalock clamp, the distal aorta by an aortic clamp (*A*). A small rent in the aortic wall was made at the level of the coarctation while mobilizing the aorta. This was repaired and the proximal aorta controlled by an aortic clamp until the end-to-side subclavian-aortic anastomosis (*B*) was completed.

At operation there was tremendous dilatation of the vessels of the posterolateral thoracic wall. The coarctation, located immediately distal to the origin of the greatly enlarged left subclavian artery, was not complete, as blood traversed the area to enter the distal aorta. A thrill was easily palpable at the coarcted segment. The intercostal vessels below the area of constriction were tremendously enlarged, although proximally they were of normal size. The aortic arch was hypoplastic, and slight poststenotic dilatation of the distal descending aorta was noted.

Several of the enlarged intercostal arteries were divided in order to mobilize the aorta both proximal and distal to the coarcted segment. The hypoplastic arch was bound down rather intimately so that further mobilization was deemed unwise. For this reason, and because the coarctation was incomplete, thereby allowing some measure of blood flow, it was decided to anastomose the enlarged subclavian artery to the aorta distal to the coarctation (Blalock-Park procedure). The aorta was occluded by the application of aortic clamps proximal to and beyond the coarcted segment. The end of the subclavian artery was anastomosed to the side of the aorta with 00000 oiled arterial silk sutures laid in such a manner that the intima was everted (Fig. 2). Brisk hemorrhage which occurred from the posterolateral area of the anastomosis when the aortic clamps were removed was controlled by a single suture. The aortic clamps had been applied for fifty-five minutes.

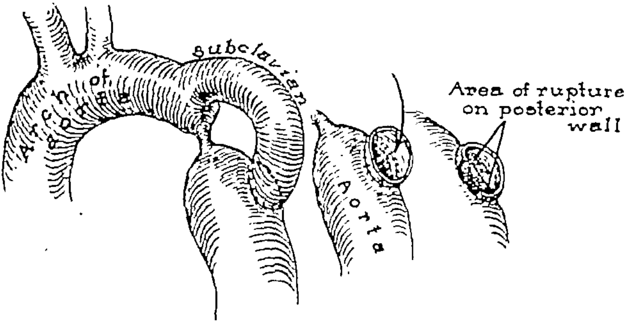

Fig. 3 (Case 1).—The anastomosis had broken down along its posterior extent. The margins of the perforation were extremely friable and contained remnants of the arterial sutures. There was but little evidence of healing.

The arterial pulsations in the lower extremities, including those of the dorsalis pedis and posterior tibial arteries, were easily palpable after operation. The peripheral arterial tension in the right arm reached 180/88 mm. Hg, while a pressure of 110 to 118 systolic was recorded in the lower extremities. During the first fourteen days following surgery, the patient was relatively symptom-free, save for the development of anemia which required the administration of 1,000 c.c. of whole blood. By that time, however, no fluid was being obtained from chest aspirations, although clinically and roentgenologically there was a large amount of fluid in the left pleural cavity. The patient began to complain of pain deep within the left hemithorax, in the left upper quadrant of the abdomen, and in the left flank. Of particular significance, on the fourteenth postoperative day, was the hemoglobin value of 75 per cent, which represented a 21 per cent decrease in a three-day period. We were unable to account for the loss of that amount of blood into the left pleural cavity. After two more transfusions and an intercostal nerve block to relieve incisional pain, his general condition improved markedly, although his temperature reached 39° C. daily. The dosage of penicillin was increased and in addition sulfonamide therapy was instituted. Repeated blood cultures produced no bacterial growth.

On the twenty-fourth postoperative day, the patient complained of progressively severe pain in the left posterior portion of the chest. There was marked tenderness in the left costovertebral angle, and although the patient appeared very pale, the hemoglobin value was 85 per cent. The urine contained no sulfonamide crystals. Since the similar episode on the fourteenth postoperative day we had been acutely aware of the probability of intrathoracic hemorrhage arising from the anastomotic line. It was our hope that conservative therapy with blood replacement would allow eventual healing of the line of anastomosis. The hematocrit values fell from 39 to 33 per cent within the next few days in spite of two blood transfusions.

A sudden shocklike state developed on the twenty-eighth postoperative day. Exploratory operation was performed immediately. The left pleural cavity was full of clotted blood which had compressed the lung to no more than 40 per cent of its normal size. The suture line had broken down on its posterolateral aspect so that there was a defect into which one could insert the tip of the little finger. Before any attempts at repair could be made, the patient died. Cardiac massage and intracardiac adrenalin were without avail.

The margins of the perforated area were composed of extremely friable, gray tissue which was almost jelly-like in consistency. The posterior wall of the aorta at the level of the anastomosis had been displaced posteriorly by the contraction of organizing fibrous tissue in this area (Fig. 3). It is possible that the posterior retraction of the organizing fibrous tissue together with the pressure within the subclavian artery produced increasing tension on the anastomosis sufficient to cause necrosis with resulting fatal hemorrhage. The other possibility is that the line of anastomosis may have been subjected to unusual pressures and currents from the flow of blood through the intact coarcted segment.

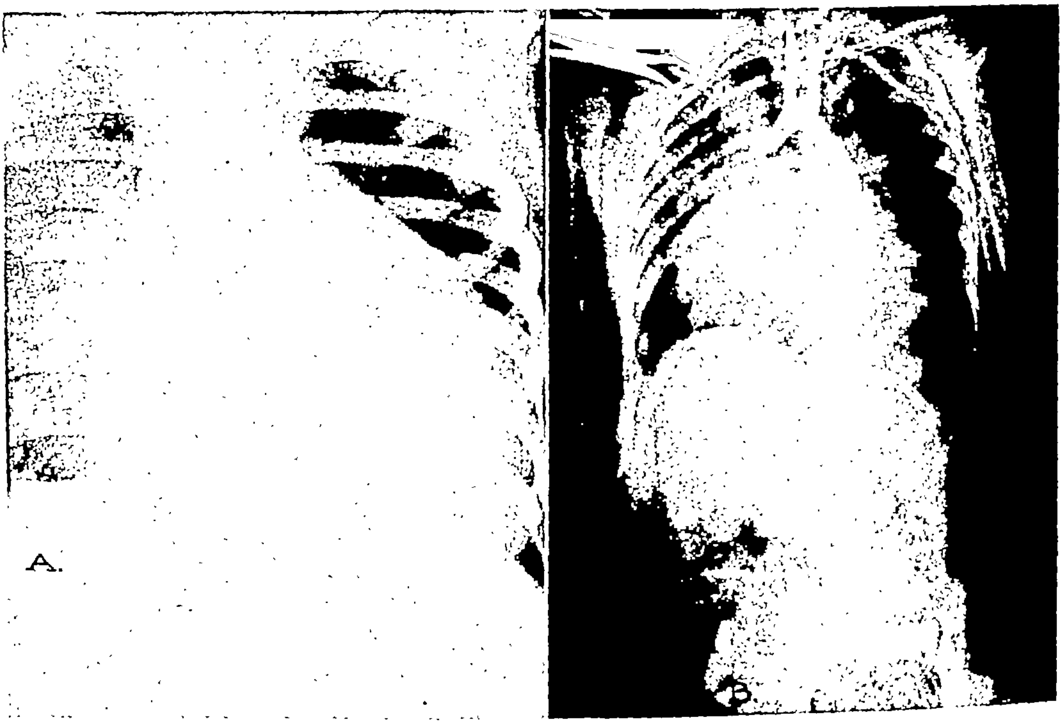

Fig. 4 (Case 2).—The plain roentgen film (*A*) showed a globular-shaped heart that was markedly enlarged with left ventricular predominance. Retrograde carotid arteriography (*B*) demonstrated coarctation of the aorta (*arrow*) at the level of the ductus arteriosus. The internal mammary artery was enlarged and the abdominal arterial trunks were well outlined.

Case 2.—D. B., aged 4½ years, entered the University of California Hospital in May, 1947. His parents had noted easy fatigability and exertional dyspnea since the age of 15 months when the child began to walk. Five months before admission, the dyspnea and fatigue with exertion became more pronounced. Occasionally it was noted that his legs were exceptionally weak and quite cold.

On admission, the patient was undersized, pale, dyspeic, and had a rather severe though nonproductive cough. There was a moderate edema of the face, trunk, and extremities. The lower extremities were underdeveloped, the precordium was prominent, and engorgement of the neck veins was evident. The heart was markedly enlarged and a systolic murmur was heard in the left third and fourth anterior interspaces. The arterial pulsations were not palpable in the lower extremities, while those in the upper extremities exhibited normal pulsatile expansion. The blood pressure in the upper extremities was 120/78 mm. Hg; that in the legs was 106/90. Although the liver was enlarged and slightly tender, the spleen was not increased in size.

A plain roentgen film of the chest showed a globular-shaped heart that was markedly enlarged, mainly to the left (Fig. 4, *A*). The electrocardiographic tracing indicated marked right ventricular hypertrophy.

The cardiac decompensation was effectively managed by bed rest and digitalization. After sixteen days of such treatment, a retrograde carotid arteriogram was done which showed a definite constriction in the aorta just beyond the arch in the region of the ductus arteriosus (Fig. 4, *B*).

At operation the heart was enlarged, especially the left ventricle and left auricle. The area of coarctation was 1.5 cm. below the point of origin of the left subclavian artery. There was a moderate amount of poststenotic dilatation, although the aortic arch was not hypoplastic. The absence of enlarged collateral vessels was rather surprising.

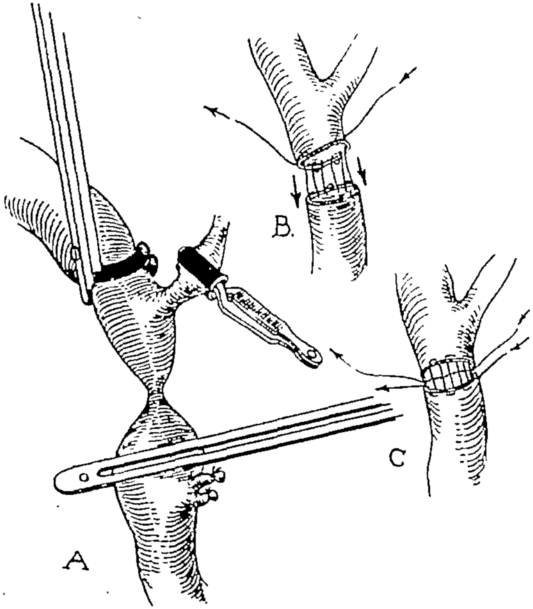

Fig. 5 (Case 2).—The proximal aorta, the left subclavian artery, and the distal aorta were controlled by appropriate clamps. After excision of the coarcted segment (*A*), an end-to-end anastomosis of the transected aortic ends was accomplished using 00000 arterial silk carried on an atraumatic needle (*B* and *C*).

The aortic arch, the left subclavian artery, and the descending aorta including the coarcted segment were mobilized. The area of coarctation was isolated by applying a Blalock clamp on the aorta proximal to the origin of the left subclavian artery and an aortic clamp similar to a Gross aortic clamp 2.5 cm. distal to the constricted area. A bulldog clamp occluded the left subclavian artery peripherally. The aorta was transected on each side of the area of coarctation and a segment 1.3 cm. in length was removed, the aortic continuity being re-established by anastomosis of the transected ends with 00000 oiled arterial silk carried on an atraumatic needle (Fig. 5). The aorta had been occluded for thirty-two minutes. The clamps were removed slowly, approximately six minutes being required for complete release. Examination of the excised segment showed a circular constriction whose aperture measured only 1.5 mm. in diameter.

The patient's postoperative course was entirely uneventful, although digitalis was administered throughout his hospital stay. The arterial pulsations in the lower extremities became normally palpable.

The boy is much more alert and active and, according to his mother, likes to do things that did not hold an attraction for him previously. The anteroposterior diameter of the chest has decreased, and he has no undue fatigue nor dyspnea. A roentgen film taken one month after surgery (Fig. 6, *A*) showed a diminution in the size of the cardiac silhoutte with changes most marked in the region of the right and left ventricles. No appreciable change was noted in the size of the left auricle. Films taken ten months after surgery showed a still greater decrease in the size of the heart, although the left ventricle and auricle were still enlarged (Fig. 6, *B*).

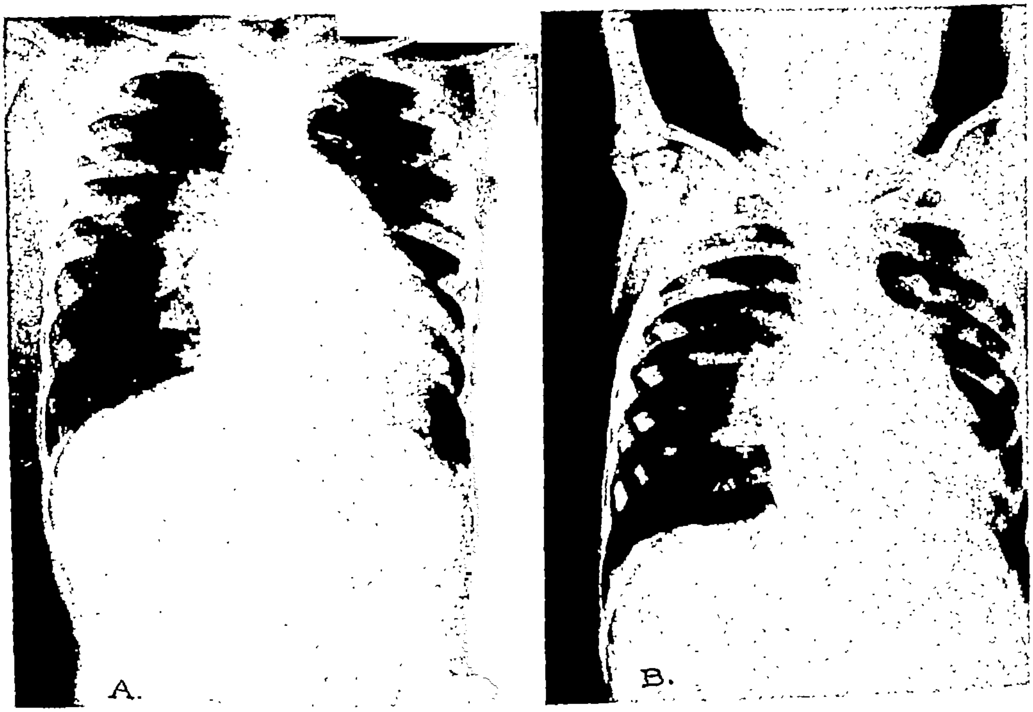

Fig. 6 (Case 2).—Plain roentgen films one month (*A*) and ten months (*B*) after operation show a progressive decrease in the size of the heart although both the left auricle and the left ventricle remain enlarged.

Case 3.—R. M., age 13½ months, was a full-term infant who had been delivered without untoward event by cesarean section after a normal pregnancy. A heart murmur was noted at birth. He had always had rapid respirations, and for five months the parents had noted a precordial bulge. Two weeks before admission he developed progressive edema of the face and lower extremities and evidenced rather marked orthopnea.

The child weighed 16 pounds, 9 ounces, was dyspneic, and exhibited signs of cardiac decompensation with edema of the face, hands, feet, and scrotum and less marked edema of the rest of the body. The chest was symmetrical except for a slight precordial bulge. The heart was enlarged 1.5 cm. beyond the right parasternal line and reached the left anterior axillary line. The cardiac rhythm was regular. A systolic murmur was audible over the entire precordium, but was maximal in the third left interspace and was transmitted to the upper back. The liver was enlarged to the level of the umbilicus but the spleen was not palpable. The radial pulses were of good quality and the arterial tension in the upper extremities was 130/85 mm. Hg. The lower extremity pulses were less easily palpable and the arterial tension was difficult to determine reliably but was in the neighborhood of 85/70 mm. Hg.

Plain roentgen films of the chest showed marked cardiac enlargement, predominantly left sided (Fig. 7, *A*). The electrocardiographic tracing showed evidence of marked right ventricular hypertrophy.

Digitalis was administered and an adequate maintenance dose continued for a two-week period. Despite this therapy the patient continued to manifest congestive failure with orthopnea, rapid respirations, peripheral edema, and hepatomegaly. It was our opinion that the maximum effect from digitalization had been obtained and no further amelioration of the decompensated state could be expected. It was agreeable with all concerned to proceed with the diagnostic and therapeutic procedures.

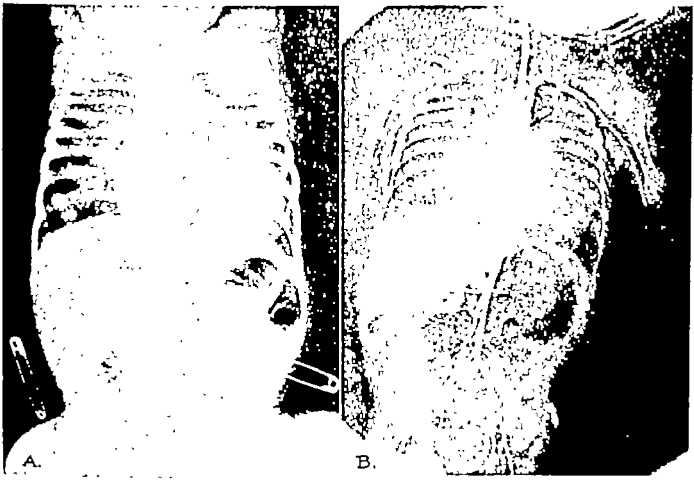

FIG. 7 (Case 3).—The plain roentgen film shows that the heart was markedly enlarged with left ventricular predominance (*A*). Retrograde carotid arteriography (*B*) verified the presence of a coarctation (*arrow*) at the level where the ductus arteriosus would be expected to enter the aorta. A moderate amount of poststenotic dilatation of the aorta was present.

Retrograde carotid arteriograms demonstrated a coarctation at about the level where the ductus arteriosus would be expected to enter the aorta. There was moderate poststenotic dilatation (Fig. 7, *B*).

Surgery was performed after twenty-seven days of preoperative preparation designed mainly to combat cardiac decompensation. The vasculature of the left posterolateral chest wall was not excessively increased or engorged. The aorta at the level of the ductus arteriosus exhibited an area of coarctation 2 cm. distal to the subclavian artery beyond which was an area of poststenotic dilatation. The aortic arch was definitely hypoplastic and a thrill was palpable in the immediate area of constriction. The distal aortic arch, the subclavian artery, and the descending aorta including the coarcted segment were mobilized by dividing the enlarged intercostal vessels and the adjacent fibroareolar tissue. Two small aortic clamps were applied proximal and distal to the coarcted segment, a 1.0 cm. segment including the constricted area was excised, and an end-to-end anastomosis between the divided ends of the aorta accomplished. The lumen of the constricted segment at the site of the stenosis measured 1.0 mm. in diameter. The aorta had been occluded for twenty-four minutes. The distal aortic clamp was removed without consequent hemorrhage, after which the proximal aortic clamp was removed very slowly. The blood pressure fell from 110 to 60 mm. Hg (systolic) immediately after the release of the proximal clamp, but rose gradually to 95 mm. Hg.

The chest incision was closed, the dressing applied, and the endotracheal tube was about to be removed when the patient's heart ceased functioning. The usual resuscitative measures were without avail. Post-mortem examination failed to demonstrate the cause of death. In retrospect, we believe that cardiac arrest ensued because of the marked diminution of peripheral resistance produced by the removal of the constricted aortic segment. Although a full four minutes was required for the complete release of the aortic clamps, the peripheral arterial tension was not sufficiently maintained.

CASE 4.*—C. S., a 34-year-old white man, had no symptoms referable to the cardiovascular system until the age of 20 years when, while being treated for pneumonia, he was told that he possessed a heart murmur and was advised to limit his activities. However, the patient felt completely well and carried on an active athletic life, playing a great deal of tennis without difficulty. He was completely well until 1945 (aged 33 years). At that time, he first noted dyspnea while climbing stairs. Within a few months the exertional dyspnea had become sufficiently marked to require slow ascent of steps and long periods of rest after even mild exercise. By February, 1946, the patient had become markedly dyspneic even with mild exertion and noted an occasional aching substernal pain. Two months later nocturnal dyspnea appeared and walking on level ground became extremely difficult.

The common carotid and subclavian arteries pulsated vigorously. The radial pulses were prominent but a marked lag in the femoral pulses was noted. The ankle pulses were faintly palpable on the right but were not discernible on the left. Bruits were audible over the left anterior and posterior thoracic wall, the latter as far inferiorly as the ninth dorsal segment. The heart was moderately enlarged and there was a systolic thrill which was maximal in the left third interspace. The harsh aortic systolic murmur was heard best over this same area and was transmitted posteriorly.

The plain roentgen film of the chest showed a dilated aorta and notching of the ribs. The electrocardiogram revealed left ventricular hypertrophy. Retrograde carotid arteriograms were suggestive of coarctation but were not conclusive. Repeated blood cultures failed to reveal bacterial growth.

At operation, the arterial supply of the posterolateral chest wall was greatly increased and the individual vessels were enlarged and tortuous. The collateral arterial circulation within the left hemithorax was enormous, especially the fourth and fifth intercostal arteries which measured about 1.0 cm. in diameter at their junction with the aorta. The internal mammary artery was huge and had a forceful pulsation. The upper three pairs of intercostal arteries were divided and ligated. The aorta at the level of the coarctation was narrowed to a diameter of approximately 1.5 cm. It was moderately dilated above and below. The aorta was occluded proximal to the subclavian artery and distal to the coarcted segment while the subclavian artery was occluded distally. The coarcted segment was resected. The aperture at the site of the stenosis was only 2 mm. in diameter. The intima of the aorta above the level of the coarctation exhibited definite yellow patches of arteriosclerosis and that below the level of the coarctation was somewhat friable. An end-to-end anastomosis of the transected aortic ends was accomplished with no little difficulty. The aorta had been occluded for eighty minutes. The aortic clamps were removed slowly, three minutes elapsing for the removal of the proximal aortic clamp. During release of this clamp, an infusion of whole blood was administered into the right radial artery. The infusion was given rapidly because the arterial pressure fell rapidly to as low as 40 mm. Hg, at which time the cardiac rhythm was extremely irregular, even exhibiting momentary arrest. By cardiac massage and reapplication of the aortic clamps, regular cardiac rhythm was re-established. However, with the maintenance of adequate cardiac activity, considerable hemorrhage occurred from the anastomotic line. This was controlled by the application of a pledget of oxidized cellulose directly to the suture line.

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*This case is being reported through the kindness of Dr. Norman Freeman, who studied and operated upon the patient.

The postoperative course was relatively uneventful until the eleventh postoperative day when the patient suddenly complained of severe left precordial pain, rapidly became comatose, and died within a few minutes. Necropsy examination showed but little healing of the suture line. About 0.5 cm. proximal to the line of anastomosis was a small perforation in the aortic wall through which extensive hemorrhage had occurred. The transverse aortic arch was atherosclerotic and the aortic valves were stenotic. The cerebral vessels were also atherosclerotic.

CASE 5.—E. B., a 19-year-old white man, was known to have had hypertension since the age of 15 years, when he consulted a physician because of headaches and occasional dizziness. There was no progression of symptoms until six months before admission, when he noted increased fatigability, more frequent headaches, several episodes of faintness with blurred vision, exertional dyspnea, and palpitation. He had not been aware of ankle edema, orthopnea, or chest pain.

On examination, prominent intercostal arterial pulsations could be palpated over the posterior mid-chest. The heart was not enlarged but a loud systolic murmur could be elicited both over the precordium and over the left posterior part of the chest. The arterial tension in the upper extremities measured 180/102, while a value of approximately 94/60 was obtained in the right leg. The blood pressure in the left leg was not obtainable. The femoral pulsations were bilaterally present but extremely weak and the arterial pulses at the foot and ankle were not palpable.

A plain roentgen film of the chest showed that the heart was moderately enlarged and that the increase in size was predominantly left ventricular. Minimal notching of the ribs posteriorly was noted, and the aortic knob was absent. The electrocardiogram was indicative of left ventricular hypertrophy. The venous pressure measured 13.5 cm. of water. Intravenous urograms revealed no abnormal findings.

Imperfect visualization of the aorta was obtained by the retrograde carotid arteriograms, but there was strong evidence from these studies that a coarctation was present immediately distal to the origin of the left subclavian artery.

At operation the coarctation was located 1.0 cm. distal to the point where the left subclavian artery emerged from the aorta. Many enlarged collateral vessels entered the aorta distal to the coarcted segment, although there was no poststenotic dilatation. The left subclavian artery was considerably enlarged. This vessel, along with the transverse arch and that portion of the aorta containing the coarcted segment, was completely mobilized. The proximal aorta was occluded by a Bethune lobectomy clamp and the aorta distal to the constricted segment by a straight aortic clamp. The aorta in the area of coarctation was transected and the proximal end closed by a running 00000 Deknatel silk suture. An end-to-end anastomosis between the subclavian artery and the distal aorta was then accomplished (Fig. 8). The occluding aortic clamps were in place for seventy minutes. Prior to the release of the aortic clamps, pneumatic cuffs previously applied to both lower extremities were inflated to prevent pooling of the blood in the legs (Fig. 9). After the aortic clamps had been slowly removed, the pneumatic cuffs were released at fifteen minute intervals. There was no change thereafter in either the cardiac rhythm or the blood pressure recordings.

The femoral and pedal pulses were easily palpable immediately after surgery and have maintained their quality. The arterial tension in the upper extremities has remained elevated in the neighborhood of 180/100 mm. Hg. and that of the lower extremities can now be recorded at 190/120. It is still too soon after surgery (three weeks) to attempt to foretell whether or not the existent hypertension will be maintained.

CASE 6.—R. H., aged 6½ years, had had frequent upper respiratory tract infections and had gained weight poorly since birth. For two years before entry his parents had noted that he had increased fatigability and for the previous six months he had almost daily severe headaches. Four months before admission a heart murmur was discovered but its etiology could not be determined.

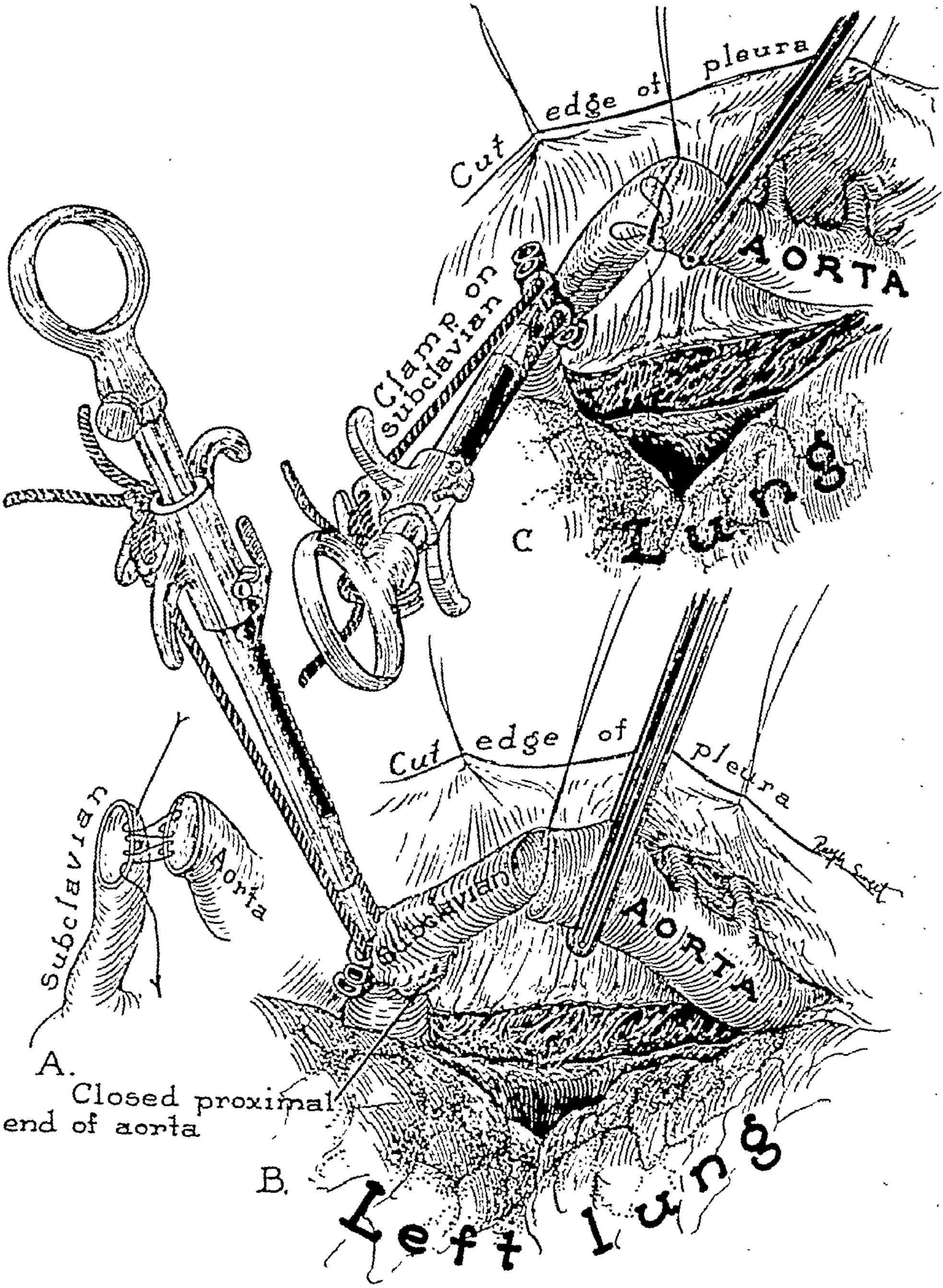

Fig. 8 (Case 5).—The aorta was occluded proximally by a Bethune lobectomy clamp, distally by an aortic clamp. The aorta in the area of the coarctation was transected and the proximal end closed (*B*). An end-to-end subclavian-aortic anastomosis was performed. The posterior suture line was first applied (*A*), after which the anterior row of sutures was laid to complete the anastomosis (*C*).

The child was somewhat small for his age and in comparison to the parental stock. A transmitted systolic murmur could be heard along the carotid arteries, more so on the left than on the right. A systolic murmur was present over the entire precordium but was most audible in the second interspace just to the right of the sternum. The murmur was transmitted both to the back and into the left axilla. The arterial tension in the left arm was 140/75 mm. Hg, while neither a pressure nor a pulse was obtainable in the right arm. The femoral and pedal pulses were likewise not palpable, nor could a blood pressure reading be determined in the lower extremities.

The *plain roentgen film of the chest showed a small notched defect on the inferior* border of the left fifth rib. The heart was not enlarged. During the first attempt to perform contrast angiography, considerable Diodrast solution extravasated into the periarterial tissues as far inferiorly as the transverse arch, obscuring the detail in this region to such an extent that it was necessary to repeat the procedure. A second series of arteriograms demonstrated beyond doubt the presence of coarctation of the aorta at the beginning of the descending portion of the aortic arch (Fig. 10).

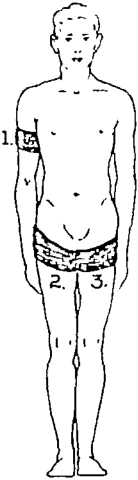

Fig. 9.—Pneumatic cuffs about the proximal portions of the extremities serve both to prevent pooling of blood in the large vascular beds and to maintain an increased resistance when the aortic clamps are removed.

At operation there was considerable reaction about the aortic arch due to the previously extravasated Diodrast solution. This made the operative procedure more difficult than would have otherwise been the case. The coarctation was located at the level of the obliterated ductus arteriosus. The left subclavian artery was very large and emerged from the parent vessel immediately proximal to the area of coarctation. *A large anomalous vessel approximately* one-half the size of the left subclavian artery joined the aorta immediately proximal to the coarctation.

The transverse aortic arch, the left subclavian artery, and the aorta distal to the coarcted segment were mobilized as completely as justifiable in the presence of the previously mentioned inflammatory reaction. Because of the proximity of the coarcted segment to the subclavian artery, an end-to-end anastomosis between the divided ends of the aorta was quite impossible. The proximal aorta was occluded by a Bethune lobectomy clamp, the distal aorta by a straight aortic clamp, and the anomalous vessel by a bull-dog clamp. An end-to-side anastomosis was then accomplished between the end of the subclavian artery and the side of the aorta distal to the coarcted segment. The occluding aortic clamps had been in place for forty-five minutes. The area of constriction was not excised (Fig. 11). Before removal of the aortic clamps, pneumatic cuffs previously applied to the lower extremities were inflated to prevent pooling of blood in the legs. The aortic clamps were removed slowly, after which the pneumatic cuffs were released individually at fifteen minute intervals. No cardiac irregularity or significant change in blood pressure readings occurred.

At the conclusion of the operative procedure, the pedal pulses were found to be strong and bounding and have remained so. The tension in the right arm now measures 120/100, while the readings in the lower extremities are 152/110 in the right leg and 160/110 in the left leg, seven weeks after surgery.

On the patient's tenth postoperative day, a marked weakness of the musculature of the left lower leg was noted and shortly thereafter some weakness of the muscles of the right posterior cervical region was thought to be present. Because of these complications the postoperative hospital stay was prolonged (seven weeks). The course was otherwise entirely uneventful and, moreover, the opportunity was presented for observing the metamorphosis of an inactive, introspective, shy, and easily fatigued child into one who shares rather marked activity with the other little patients on the ward.

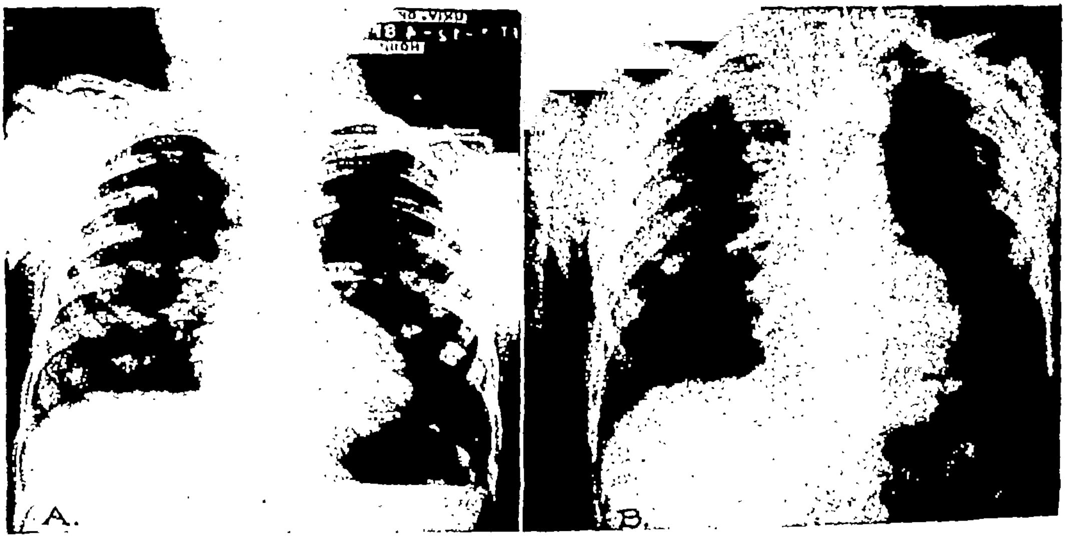

Fig. 10 (Case 6).—The plain roentgen film showed a small notched defect on the inferior border of the left fifth rib. The heart was not enlarged (*A*). Retrograde carotid arteriography showed a definite coarctation (*arrow*) in the first portion of the descending aorta (*B*).

DISCUSSION

It has been mainly through the efforts of Crafoord in Sweden and Gross in America that the surgical attack upon coarctation of the aorta has achieved success. This particular realm of surgical endeavor, though still in its infancy, has offered new hope and promise to those unfortunate people afflicted with the anomaly. Although there are no doubt many cases still unreported in the literature, an analysis of those reported through March, 1948, is of interest. Table I indicates that most of the operations have been performed by Gross and Crafoord. Of the forty-five patients operated upon in the hope of carrying the procedure to its completion, forty were subjected to some form of excision and/or anastomosis. In this group of forty patients, there were nine deaths, a mortality of 22.5 per cent. It is reasonable to assume that when a larger number of cases has been reported, the mortality rate will approximate that of other surgical procedures of similar magnitude.

The collected data are in no sense complete, but it is apparent that the majority of deaths occurred in those patients who had reached adulthood. This does not signify that age is an absolute contraindication to operation, but rather emphasizes the fact that a guarded prognosis must be made when operation is the only hope of salvation for these people. Considering the magnitude of the operative procedure and the danger of working with vessels of aortic caliber, the fact that good results are obtained in 62 per cent of cases is gratifying.

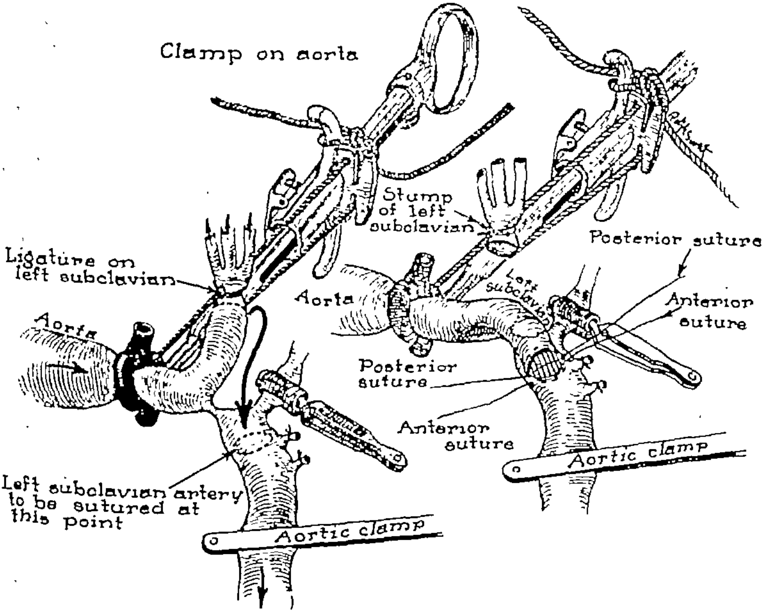

Fig. 11 (Case 6).—The proximal aorta was occluded by a Bethune lobectomy clamp, the distal aorta by an aortic clamp. A large anomalous vessel sprung from the posterolateral portion of the aorta immediately distal to the coarctation and was controlled by a bulldog clamp. An end-to-side subclavian-aortic anastomosis was accomplished without resection of the constricted segment.

That four of the nine deaths occured from postoperative hemorrhage is not surprising. Two others occurred from marked interference with cardiac function, probably occasioned by the release of peripheral arterial resistance due to removal of the constricted segment. The remaining causes of death appear to be related both to the consequences of operation upon large blood

TABLE I.—RÉSUMÉ OF REPORTED OPERATIVE CASES IN THE WORLD LITERATURE

AUTHOR	EXPLORATION (NUMBER OF CASES)	OPERATION (NUMBER OF CASES)	DEATHS	CAUSE OF DEATH	AGE OF PATIENTS WHO DID NOT SURVIVE	ANESTHESIA	NUMBER OF GOOD RESULTS
Gross	18	15	2	1. Cardiac dilatation and irregularity upon release of aortic clamps	5 yr.	Cyclopropane	12 patients of 15 (2 deaths, 1 hypertension not relieved because of unsatisfactory anastomosis)
				2. Death 24 hr. postoperatively, probably from hemorrhage from suture line	30 yr.		
Crafoord	17	15	2	1. False aneurysm at aortic suture line	Unknown	Cyclopropane and nitrous oxide	11 of 15 (2 deaths, 2 inoperable)
				2. Postoperative hemorrhage from large intercostal vessel (anastomosis intact)	Unknown		
Clagett	1	1	0			Not noted	1 (age of patient, 34 yr.)
Jaehning	3	3	2	1. Massive atelectasis of left lung, and pulmonary edema of right lung	16 yr.	Not noted	1 of 3 (2 deaths)
				2. Atelectasis of left lung, and obstructive emphysema of right lung	21 yr.		
Stephens and Grimes	6	6	3	1. Postoperative hemorrhage at suture line	16 yr.	Nitrous oxide and curare	3 of 6 (3 deaths)
				2. Postoperative hemorrhage above suture line	34 yr.		
				3. Probable cardiac irregularity and dilatation	13½ mo.		
Total	45	40	9 (22.5%)	1. Hemorrhage postoperative, 4 2. Cardiac irregularity, 2 3. Atelectasis and edema, 2 4. Aneurysm at suture line, 1			28 (62.2%)

vessels and to the magnitude of the procedure and its profound alteration in cardiovascular-respiratory physiology.

The six cases reported here constitute but a fraction of those reported to this date in the literature. However, it seems to us that all available experience with the surgical treatment of coarctation of the aorta should be pooled for the mutual benefit of all. The results of the experiences at the University of California Hospital are briefly summarized in Table II. End-to-end anastomosis was performed in three cases, an end-to-side anastomosis between the left subclavian artery and the aorta without excision of the constricted segment in two cases, and an end-to-end anastomosis between the end of the subclavian artery and the distal aorta after excision of the area of coarctation was done in one case. There is general agreement that an end-to-end union is the treatment of choice whenever possible. The site of origin of the coarctation is the main factor which determines the type of procedure to be done. If the coarcted area is situated close to the point where the subclavian artery emerges from the aorta, resection with end-to-end anastomosis is contraindicated because of the distance between the two aortic segments. Our experience with Case 1, in which the suture line of the end-to-side subclavian-aortic anastomosis broke down, suggests that an end-to-end union between the distal transected aorta and the subclavian artery might offer distinct advantages over the so-called Blalock-Park procedure which leaves the coarcted area intact.

Many authors feel that few, if, any, of the intercostal arteries should be sacrificed since they form collateral vascular channels. It is probable, however, that the danger of complicating or fatal hemorrhage from an inadequately controlled aorta is far more serious than is the sacrifice of a minor area of collateral vessels. In addition, the constrictionless aorta assumes all the blood transport previously carried by the collateral vasculature.

In two cases, hemorrhage from or near the suture line led to fatal termination. In one of these, even though the suture line showed but little evidence of healing at necropsy, the site of exsanguinating hemorrhage was well above the anastomosis. It is reasonable to assume that the aortic perforation occurred from the trauma of the occluding aortic clamp in an area exhibiting atherosclerosis. In the other case, perforation occurred at the suture line, presumably from excessive tension or from abnormal influences upon the suture line resulting mainly from the presence of the open coarctation.

The one fatality on the operating table exhibited no direct cause of death at autopsy. It seems likely that the child died from the effects of acutely disturbed cardiovascular physiology. One would expect immediate evidence of cardiac failure when there is a sudden decrease in peripheral resistance, yet in this child cardiac failure did not occur until approximately thirty minutes after the aortic clamps were released. This operative mortality might have been prevented by a more gradual decrease in peripheral resistance. The application of pneumatic cuffs on the lower extremities, maintaining the cuffs at pre-resection pressure levels, and the release of the individual cuffs at fifteen minute intervals after the removal of the aortic clamps, might have provided an adequate mechanism to accustom the heart to a new level of

TABLE II. RÉSUMÉ OF CLINICAL AND OPERATIVE DATA, UNIVERSITY OF CALIFORNIA HOSPITAL

AGE	SEX	LOCATION OF COARCTATION		OPERATIVE PROCEDURE			SEQUELAE	TIME AORTA OCCLUDED (MINUTES)
		1.5 TO 2.0 CM. DISTAL TO ORIGIN OF SUBCLAVIAN ARTERY	IMMEDIATELY DISTAL TO ORIGIN OF SUBCLAVIAN ARTERY	RESECTION WITH END-TO-END ANASTOMOSIS	END-TO-SIDE ANASTOMOSIS BETWEEN SUBCLAVIAN AND AORTA	END-TO-END ANASTOMOSIS OF SUBCLAVIAN ARTERY TO DISTAL AORTA WITH EXCISION OF COARCTATION AND CLOSURE OF ITS PROXIMAL END		
13½ mo.	M	X		X			Operative mortality	24
4½ yr.	M	X		X			Well	32
6½ yr.	M	X			X		Well	45
16 yr.	M		X		X		Hospital mortality	55
19 yr.	M		X			X	Well	70
34 yr.	M	X		X			Hospital mortality	80

peripheral resistance. Particularly is this true in the younger age groups. Rapid whole blood infusions while the aortic clamps are being removed accomplishes much the same thing.

At this moment there is nothing to offer those unfortunate people with areas of narrowing, usually in the descending aorta, which are of such length that it is impossible to re-establish continuity by an appropriate anastomosis. Save for this unfortunate contingency, there is no absolute contraindication to the surgery of coarctation of the aorta. Advanced age with its attendant arteriosclerotic changes, especially in the proximal aorta, in combination with other factors, may constitute an absolute contraindication in the specific case, but perhaps only relative reasons against operation in others.

The condition of the proximal aorta is all important. A dilated, attenuated, and weakened proximal aorta whose intima is studded with arteriosclerotic patches is likely to hold sutures poorly. It is generally agreed that in many cases, although poor results may be expected, surgery must be performed as the only hope for salvation of the patient. It is emphasized that one can expect better results in the child or young adult in whom degenerative changes have yet to appear.

SUMMARY

In the adult type of coarctation, a sharp constriction or obliteration of the descending aorta occurs at or near the insertion of the ductus arteriosus. The aorta proximal to the coarctation is especially likely to develop inflammatory or degenerative changes, the exact cause of which is unknown. There is no doubt that coarctation of the aorta shortens the life of the individual. Cardiac decompensation, spontaneous rupture of the aorta, cerebral accidents, and mycotic endarteritis are the most frequent causes of death.

Six patients exhibiting coarctation of the aorta have been operated upon at the University of California Hospital. Three patients survived. One fatality was operative; two others, from exsanguinating hemorrhage, occurred in the immediate postoperative period. One of these resulted from necrosis at the line of anastomosis; the other, although showing but little evidence of healing at the suture line, had a small perforation proximal to the line of anastomosis. The opening apparently had occurred in an area of atherosclerosis traumatized by an occluding aortic clamp.

The operative death, in retrospect, was probably a preventable one. If the peripheral arterial resistance and blood volume had been maintained until the cardiovascular system had had sufficient time to adjust to the new pressure relationships, normal cardiac function would probably have ensued.

A brief review of the literature indicates that an over-all mortality rate of 22.5 per cent exists for the surgery of coarctation of the aorta. Most of the reported deaths have occurred in patients in older age groups and the most common cause of death has been hemorrhage, usually at the line of anastomosis. It is guite generally agreed that an end-to-end aortic anastomosis is the procedure of choice.

We have operated upon three patients of 5 years or younger; one was 2½ years old and his, incidentally, was the easiest operation from a technical point of view; he had the smoothest postoperative course and he was able to go home on the tenth day after operation. Since the collateral circulation is well developed early in life in these individuals the indications are to operate upon them early. We have employed a variety of methods in our end-to-end anastomoses of the aorta, but at present prefer the use of four everting stay sutures combined with four running over-and-over sutures in the four quadrants.

DR. ROLLINS HANLON, Baltimore.—On Dr. Blalock's service at The Johns Hopkins Hospital twenty-four patients with coarctation of the aorta have undergone exploratory thoracotomy. The age of the patients ranged from 6 to 34 years, with the majority over 20 years.

There have been three deaths in the series. One resulted from a technical error, one from a cerebral vascular accident, and one from multiple associated cardiac abnormalities. The latter two deaths were in children. In one instance resection of the coarctation was not possible. Twenty patients underwent successful resection of the coarctation. In three continuity of the aorta was re-established by anastomosis of the subclavian artery to the distal aorta. In seventeen an end-to-end anastomosis was carried out between proximal and distal aorta. This is the procedure of choice.

The anatomic findings in one instance are of sufficient interest to warrant presentation. (Slide.) This 20-year-old girl had a coarctation proximal to the origin of the left subclavian artery—an abnormality which had been diagnosed by clinical studies including angiocardiography. There was notching of the ribs on the right but not on the left. There was a large left carotid artery and a somewhat smaller left subclavian artery with the intervening vertebral artery arising directly from the aorta instead of from the subclavian artery. The left radial pulse was unaffected by occlusion of the left subclavian artery, indicating excellent collateral circulation. The blood pressure in the left arm was lower than that on the right before operation, and this relation persisted after satisfactory aortic anastomosis, with the left subclavian artery divided. The subclavian artery was sacrificed since it would have interfered with an end-to-end aortic anastomosis. In resecting the coarctation, in order to have the proximal opening comparable in size to that in the distal aorta, it was necessary to extend the incision up the lateral wall of the vertebral artery. (Slide.) The completed result was quite satisfactory, and the patient remains well more than three months after operation.

In closing, three technical points may be mentioned. First, an everting mattress suture is used. Second, the collateral circulation, particularly the intercostal arteries, has been preserved if at all possible. Finally, a special clamp similiar to the Potts' clamp is used to occlude the proximal aortic segment. (Slide.) This allows blood to flow freely up the subclavian artery while occluding the aorta just distal to it, thus providing adequate working length with increased safety even in the very short proximal segments that are encountered not infrequently.

DR. CLARENCE CRAFOORD, Stockholm.—From the excellent result we have just heard from Dr. Blalock and his co-workers, and from my own experience, I think we may state that radical treatment of coarctation of the aorta can no longer be considered as a surgical equilibristic procedure; I think it can be said that it is a sound surgical procedure. The results I have had support the conclusions which can be drawn from Dr. Blalock's presentation.

We have now operated on thirty-two patients with coarctation, resection was done in thirty-one of those and in one case we did a "Blalock operation" with anastomosis, end-to-side, between the subclavian artery and the aorta below the coarctation. In this series of thirty-two cases we had two postoperative deaths, one due to acute bleeding on the afternoon of the day of operation, the other due to formation of a dissecting aneurysm which broke into the bronchial tree, from which one month after operation the patient died from massive hemoptysis. In addition to the thirty-two cases operated upon, exploration has been done in five cases, intending to try radical operation, but conditions were such that an anastomosing operation was not possible. These patients were in the older age group, between 25 and 35 years of age. In all, arteriosclerotic changes of the walls of the arteries were present, which made any kind of surgical intervention on the vessels impossible. In that group of five cases in which exploration and suture was done again we had two deaths shortly after operation. Because of that I would like to point out the value of a method of investigation that we have developed recently to try to make as accurate an anatomic diagnosis of the lesion as possible before operation. We have introduced an ordinary cardiac catheter through the radial artery, pushing it forward, down into the aortic arch. With rapid injection of 50 c.c. of 70 per cent Diodrast we can get an excellent x-ray picture of the first part of the aorta and the coarctation. I hope that as we become more familiar with this method of investigation we may be able to exclude most of the unsuitable cases from exploratory thoracotomy and select in advance the ones on whom we can hope to achieve a good result.

(Slides.) In this picture can be seen the catheter passed down into the arch of the aorta to the level of the aortic ostium. The curved outlines of the aortic valves are shown, and also a fairly good picture of the coronary arteries. We hope to be able to carry out studies on the coronary arteries by this means in the future. In the cases which this procedure had been carried out we have had no reaction which contraindicates a continuance of the method.

(Slide.) This case was rather difficult to interpret; it was one of the first upon which this investigation was done and we did not know how to interpret these different shadows. We therefore explored to confirm our x-ray findings, and in this drawing you can see what was found. There were multiple aneurysms on the aortic arch which made radical procedure of any sort impossible.

We have been able to follow twenty-seven of the thirty-two cases for a period of time ranging between three months and three and one-half years. Of the remaining five patients, two have died in the immediate postoperative period as just mentioned and three have been so recently operated upon that it is too early to tell how they will progress. In thirteen of the twenty-seven cases the blood pressure has returned to normal, with higher pressures in the legs than in the arms. In six, the blood pressure is equal in the legs and the arms and in eight, it is still slightly higher in the arms than in the legs. In these eight we have, from an anatomic viewpoint, not been able to perform a sufficiently wide anastomosis.

In three cases of the thirty patients surviving we have had development of small postoperative dissecting aneurysms, demonstrated by direct aortography after operation. Two of the three are symptomless; they have not been growing. In one case there is sign of increase in the size of the aneurysm, the patient has symptoms, and we are discussing the possibility of reoperation.

The principal difference between the technique described by Blalock and Gross and the one I use, is that both Blalock and Gross use everting sutures. I have felt that one should try to resect as much as possible of the constricted area which is nearly always so long that it is difficult to resect enough. Because of that I have used an anatomic suture with coaptation of the different layers of the aortic wall against each other, which permits resection of a few millimeters more than if an everting suture is used.

I have also preferred this suture because I believe that the healing will be better and stronger when the different anatomic layers of the aorta are in direct contact. I do not know whether Dr. Blalock and Dr. Gross have had postoperative aortograms made, or if they have found any postoperative symptomless aneurysms.

A comparison between our series in that respect might give some indication as to whether the anatomic or the everting suture is to be preferred.

The mean blood pressure before operation in my cases has been 180/100 in the arms and about 100 mm. of mercury systolic in the legs. After operation the pressure in the arms has gone back to normal as mentioned previously.

DR. OSLER ABBOTT, Atlanta.—In our more recent coarctation operations we instituted arterial transfusion in the arm on the uninvolved side to be ready at a set level of blood pressure at the time of release of the anastomosis. The fall of pressure in these patients has been to the level set on the manometer and has not gone below that level. I believe that arterial transfusion has a tremendous place at this stage of the operation. It is also interesting that this method of transfusion was recently used on the urological service at the time of removal of an adrenal chromocytoma with no drop in blood pressure.

The other factor I would like to mention is the occurrence in our series two years ago of encountering a patient in whom a large patent ductus was present, and as soon as the ductus was occluded with a rubber shod clamp, intractable auricular fibrillation occurred, which could not be corrected by any method we attempted. On releasing the patient from oxygen it became obvious that there was a third deformity, namely, a hidden pulmonary stenosis; we did not resect the coarctation.

I would also like to mention the one death in our series occurring when we tried to form an artificial arch in a patient having only two major vessels coming off the arch, namely, a combined innominate and left common carotid and a left subclavian; the coarctation was proximal to the left subclavian, and the subclavian wall was used for an artificial construction of the arch. The patient died eighteen hours after operation when the pressure rose to 134. I am certain that if we had reinforced this graft we might have been successful.

DR. CLARENCE CRAFOORD, Stockholm.—There has been some talk about the rapid fall of blood pressure caused by rapid releasing of the aortic clamps. This is difficult for me to understand. I have had the aorta crossclamped in altogether seventy cases of coarctation and patent ductus, and have never taken any precaution in releasing them slowly, with no blood-pressure falls of any significance in connection with removal of the clamps. In the ductus cases where we have no collateral circulation, when aortic clamps are applied the blood pressure rises sometimes to 200 mm. of mercury or more. The blood pressure has dropped to the previous level after the clamps have been released. I do not think the explanation given by Dr. Gross is the correct one, that it is the releasing of the clamps that is the cause of the blood pressure fall; I am convinced there is some other factor such as unsatisfactory ventilation during the anesthesia, for all these patients as far as I know are allowed to breathe themselves during the operation and have not been under controlled respiration. I am convinced that if adequate ventilation has been used the small additional stress to which the heart is subject on removal of the aortic clamps will not affect the heart at all.

There is a point I would like to stress when giving large amounts of blood rapidly. I believe it is better to give fresh blood from heparinized donors, than to give old blood. Fresh blood will function much longer than stored blood from a blood bank.

THE SURGERY OF PULMONARY STENOSIS

EXPERIENCES WITH LEFT SUBCLAVIAN TO LEFT PULMONARY ARTERY ANASTOMOSIS

EMILE HOLMAN, M.D.
SAN FRANCISCO, CALIF.

IN A DISCUSSION of Cutler's[1] startling, though unsuccessful attempts to enlarge the stenosed mitral valve by operation, Harvey Cushing in 1923 referred to the heart as the "last frontier in surgery." His keen imagination and lively intellect would have hailed with enthusiasm the recent equally startling developments in the surgical correction of congenital malformations of the heart.

The most spectacular of these developments has been the application by Blalock[2, 3, 4] of Taussig's brilliant suggestion that in children, cyanosed and incapacitated by pulmonary stenosis or atresia, the blood flow through the lungs be augmented by an artificial, surgically created patent ductus. Taussig had noted that in cases of pulmonary stenosis the patent ductus was occasionally the only route by which unaerated blood reached the lungs and that over a period of years as the patent ductus slowly closed, the children gradually became more cyanotic and died. This possibility of gradual and finally fatal closure of an essential patent ductus had been suggested previously in a discussion of congenital intracardiac fistulas.[5]

To circumvent the pulmonary stenosis, Blalock developed the surgical technique of implanting a systemic artery into the pulmonary artery. In his first case he employed implantation of the left subclavian artery into the left pulmonary artery. Subsequently he implanted the left innominate artery of a right aortic arch into the left pulmonary artery, but his usual procedure has been to implant the right subclavian artery into the right pulmonary artery. The use of the innominate artery has been found dangerously hazardous because of the cerebral complications of hemiplegia or death incident to ligation of the common carotid artery, and is therefore avoided if at all possible.

Our experiences with these various procedures have been limited to thirty-four cases. In six instances for various reasons an anastomosis between the systemic and pulmonary vessels could not or was not performed. In one of these patients, instead of a pulmonic stenosis, a complete transposition of the pulmonary artery and aorta was encountered (Fig. 1), and the small 3-year-old child died almost immediately after the opening of the chest. A second child also died before any anastomosis could be effected. He was very blue and had had in his three years of life three embolic or thrombotic phenomena, including a cerebral accident producing a permanent left hemiplegia. In a third child, the application of the Blalock clamp for occlusion of the pulmonary artery caused cessation of cardiac contractions, and after several

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such attempts, the heart ceased beating entirely. At autopsy it appeared that a barely patent and hidden ductus arteriosus lay in such a position as to be closed completely by the clamps on the pulmonary artery thus reducing the already greatly diminished blood flow to the lungs with resulting decreased aeration. In a fourth patient, 12 years of age, it was evident that the right subclavian artery could not be brought down for anatomosis to the right pulmonary artery without ligation and division of the carotid artery. Because of the high incidence of cerebral complications following ligation of the common carotid, the operative wound was closed, and it was proposed to open the left side of the chest at a later date for anastomosis of the left subclavian artery to the left pulmonary artery. However, the boy never recovered consciousness and died twelve hours later in marked and increased cyanosis. Apparently the mere administration of a general anesthetic had somehow altered the pressure relations between the systemic and pulmonary circulations (Fig. 2), causing a more than usual diversion through the interventricular septal defect of unaerated blood into the systemic circulation which was incompatible with life.

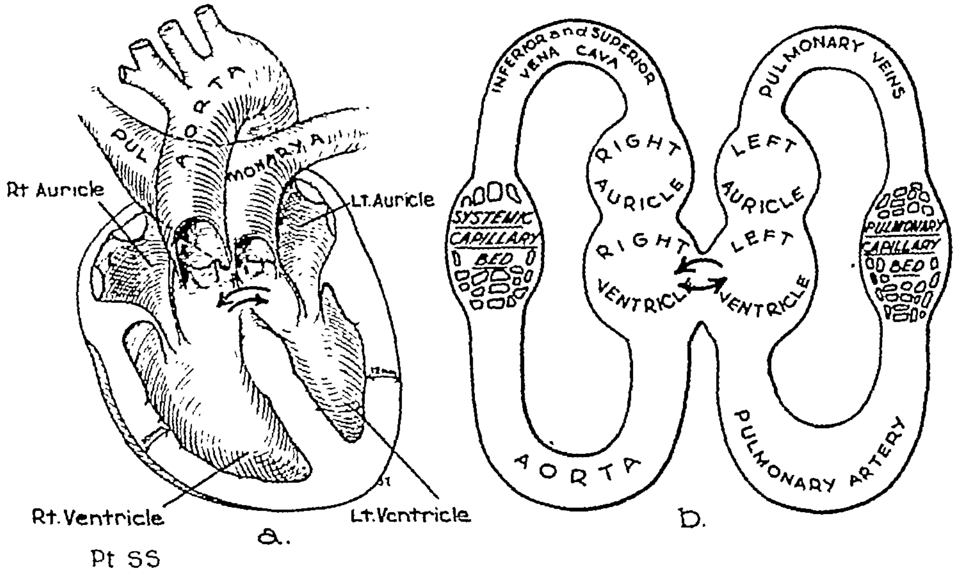

Fig. 1.—*a*, Complete transposition of pulmonary artery and aorta with an interventricular septal defect as the only communication between the systemic and pulmonic circuits.

b, Schema of circulation under these circumstances indicating that a to-and-fro flow of blood through the septal defect provided the only interchange of blood between the two systems. The increased pressure in the pulmonic circuit incident to anesthesia probably prevented the usual flow from the right heart into the left heart with a resulting greater flow of unaerated blood in the systemic circuit and death. The greater cyanosis, even under the administration of oxygen, and prompt death on opening the chest lends credence to this view.

In a fifth child, 3 years of age, the exposed pulmonary artery was 1.8 cm. in diameter and pulsated vigorously. The water manometer was not quite high enough to measure accurately the pulmonary pressure, but it was estimated to be at least 900 mm. of water. The systemic arterial pressure at that moment was 98 mm. of mercury, and it was obvious that the pressures in the two systems were approximately equal. It seemed probable that we were dealing with a truncus deformity, and no anastomosis was performed. The child died a few hours later. Only a partial autopsy was permitted, but it disclosed that the child had indeed a truncus arteriosus fed by both ventricles, thus accounting for the equal pressures in the pulmonic and systemic circulations. In a sixth child, at thoracotomy no pulmonary artery could be found on the right side, and the operation was abandoned. Two weeks later a left thoracotomy was performed, but again no pulmonary artery could be found. This 6-year-old boy is still living, no worse for the two unsuccessful explorations.

In twenty-seven cases the operation was completed with good to phenomenal improvement in twenty-four cases and death in three. The first death was in a 15-month-old infant whose operation was performed on Feb. 16, 1946. The right subclavian artery at the site of division and anastomosis to the pulmonary artery was only 3 mm. in diameter. At autopsy, thrombosis was found at the site of union, with partial angulation and obstruction of the right pulmonary artery, which had so reduced the flow of blood to the lungs that death occurred twenty-four hours after operation. This experience led to the use of the right common carotid artery in our next patient, only to have this patient develop a left hemiplegia from which she slowly recovered.

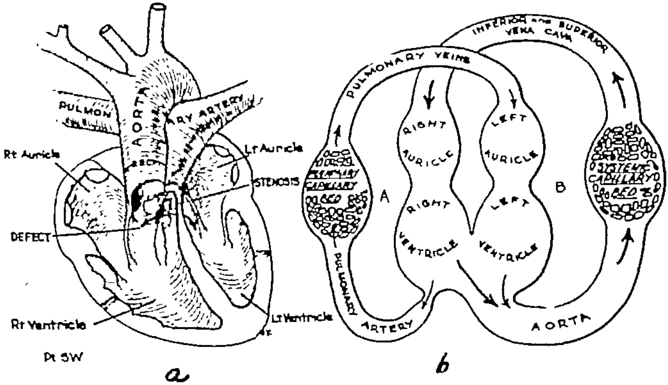

Fig. 2.—*a*, Marked pulmonic stenosis, interventricular septal defect, large overriding aorta in a 12-year-old boy who died twelve hours after simple thoracotomy.

b, Schema of circulation indicating that the increasing cyanosis and death after operation was probably explicable on the basis of an increased flow of unaerated blood into the aorta due to an increased pressure in the pulmonic circuit imposed by anesthesia.

The second death occurred in a patient in whom the ligature on the distal end of the divided subclavian artery included, besides the vessel itself, some of the connective tissue fixed to the thoracic wall so that the ligature was anchored in place. The artery, which had been pulled down out of the tissues of the neck, was therefore held in place under considerable tension. The elasticity of its wall led to its being gradually pulled out of the anchored ligature, resulting in a fatal hemorrhage two hours after the operation. The obvious lesson is to ligate doubly or to ligate and transfix the distal artery, being careful also to avoid including in the ligature any surrounding fixed tissues. An artery ligated under tension must be completely free of surrounding tissues so that it may retract into its normal position.

In the third patient, 19 years of age, who died with a hemoglobin concentration of 114 per cent, and a red cell count of 8.1 million, a very unsatisfactory anesthesia was administered, the patient's color being blue-black throughout the operation despite every effort to correct it. A good anastomosis between the left subclavian artery and the left pulmonary artery was affected, but the patient never recovered consciousness and died twenty-four hours after operation. An autopsy was not permitted, but cerebral anoxia was undoubtedly an important factor in this patient's death, as indicated by a left hemiplegia and a marked right-sided spasticity noted immediately after the operation.

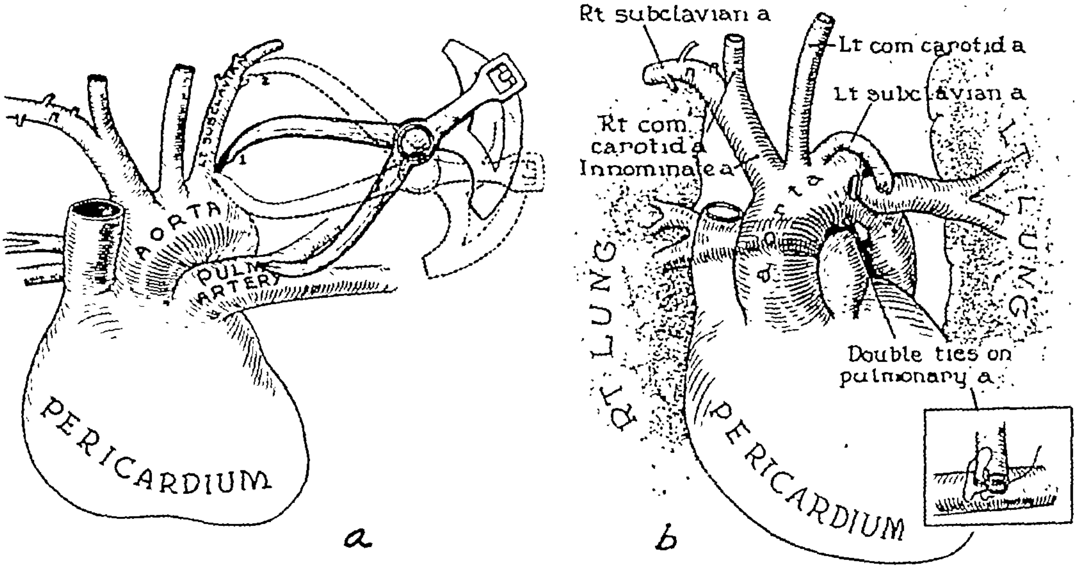

Fig. 3.—*a*, In employing the left subclavian-to-left pulmonary artery anastomsis, the distance between the base of the subclavian artery and the proposed site of anastomosis is measured by calipers, and an equal length of subclavian artery is mobilized for division at 2.

b, If the subclavian artery is sharply angulated at its orgin on opening the anastomosis, the pulmonary artery central to the anastomosis is doubly lighted and divided between ligatures, thus permitting the pulmonary artery to rise in the chest with correction of the angulation and an increased flow through the anastomsis.

In two feebleminded infants the innominate artery was sutured to the right pulmonary artery with excellent results, so far as physical activity and improvement in cyanosis were concerned. The mothers even believed there was some mental improvement.

Because of difficulties with the short right subclavian artery, and the distressing cerebral complications that may follow ligation and division of the right common carotid artery when the innominate is used the left subclavian artery was employed because of its greater length. The objection to its use has been made by Blalock, that in bringing it over the arch of the aorta the acuteness of the angle at its origin interferes with the flow of blood through it. This is a valid objection in some instances, but where such interference with blood flow occurs, it is quite obvious immediately upon releasing the clamps and opening the anastomosis. Fortunately, it is readily corrected by complete division of the left pulmonary artery between the site of the anastomosis and the primary branching of the vessel (Fig. 3). That the patient can tolerate such division has already been demonstrated by its complete occlusion during the time in which the anastomosis was being made. Such complete division was found necessary, however, in only four of the twenty-three cases (Fig. 4). In a fifth case, a 9-year-old girl, the left pulmonary artery was only 7 mm. in diameter, too small for an end-to-side anastomosis. Accordingly, the artery was completely divided, and an end-to-end anastomosis between the subclavian artery and the distal pulmonary artery was established with good functional results (Fig. 5).

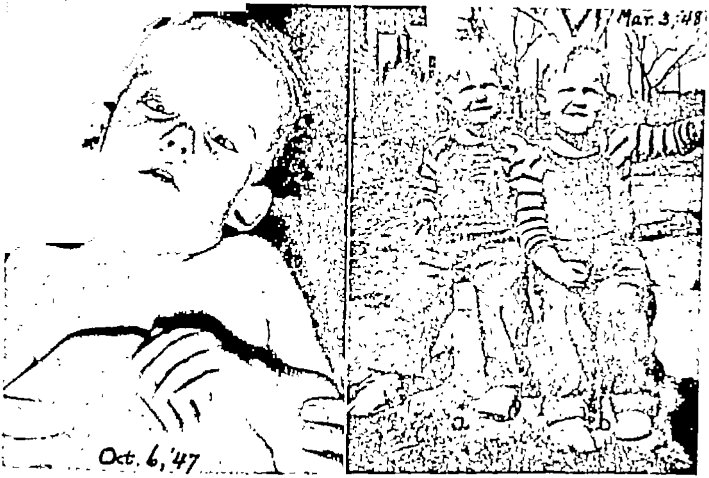

Fig. 4.—Marked muscular weakness in a cyanotic boy was completely corrected by a left subclavian to pulmonary artery anastomosis with division of the left pulmonary artery central to the end-to-side anastomosis (see Fig. 3). Following operation the patient *a* became quite as active as his twin *b*.

In nineteen cases in which the left subclavian artery was sutured to the side of the left pulmonary artery without division of the pulmonary artery, good functional results have been obtained as shown by absence or improvement in cyanosis, by greater physical activity, and by absence of dyspnea. Some patients are said by their parents to be perfectly normal. The patients have ranged in age from 15 months to 26 years. One 18-year-old was practically incapacitated by dyspnea, necessitating squatting, even in the middle of a busy street, to recover his breath before he could go on. He is now able to hold a job (watch repairing), no longer squats, and has almost a normal color.

All patients but one were considered as belonging in the general group of tetralogy of Fallot. This one exception was a 5-year-old boy whose frank cyanosis did not appear until 3 months of age. His activity was greatly limited, and cyanosis and dyspnea were aggravated greatly with the slightest exercise. He watched other children, rather than participating in their play. He had a loud systolic murmur at the base heard all over the precordium. The pulmonic second sound appeared loud and snapping. The circulation time from arm to lung was 6.5 seconds. The red cells numbered 7.8 million, and hemoglobin concentration was 142 per cent; blood pressure was systolic 110, diastolic 70. The electrocardiogram showed abnormal P waves and a left axis deviation. The roentgenogram showed a normally contoured heart. At operation the right subclavian artery, which was 8 mm. in diameter, was implanted into the right pulmonary artery 1.5 cm. in diameter. When the anastomosis was opened, the blood pressure fell to 104/56, and the pulse became accelerated from 110 to 120. Since operation, the cyanosis has practically disappeared, his physical activity is normal and as vigorous as that of his brother. The red cells now number 5.5 million and the hemoglobin concentration is 99 per cent. This patient was interpreted as having a tricuspid stenosis with an open foramen ovale, rather than a pulmonary stenosis with an open interventricular septum.

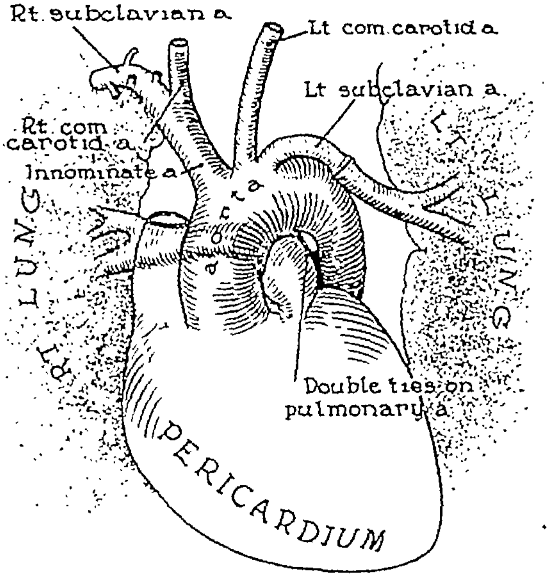

Fig. 5.—A pulmonary artery only 7 mm. in diameter may not permit an end-to-side anastomosis but will permit an end-to-end anastomosis between the subclavian and pulmonary arteries.

The use of angiograms[*] in selected cases has provided interesting and valuable help in arriving at more accurate diagnosis (Fig. 6).

Complications following operation have been few. One patient's course following operation on July 31, 1947, was characterized by a persistent chylothorax. Over 4,430 cm. of milky fluid were aspirated from the left side of the chest over a period of nine days. Intravenous alimentation with protein hydrolysate led to thrombosis of the right saphenous vein, resulting in a paradoxical embolism through the interventricular septal defect to the right cerebrum with a left-sided hemiplegia on the seventeenth day following operation. Gradual recovery took place. On Nov. 17, 1947, he was reported as being able to walk alone but was still unable to use his arm.

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[*] These were made at the insistence of Dr. Ann Purdy, whose enthusiasm and aid in diagnosis, together with the cooperation of Dr. Harold Faber, both of the Department of Pediatrics, have made this work possible.

Since this experience, lymphatics are carefully watched for, as the left subclavian artery is isolated from the mediastinum, and on one occasion a large vessel filled with clear fluid was observed to cross the operative area and was carefully avoided. In another instance turbid chylous fluid suddenly filled the operative area; the point of leakage in the mediastinum was sought, identified, and clipped with a silver clip, with no subsequent trouble.

In three patients, a chest filled with fluid led to the aspiration of 900 cm., 500 cm., and 1,200 c.c. of bloody fluid, respectively. All patients then had an uncomplicated recovery. In two of these patients pressure in the pulmonary artery had been ascertained by introducing a needle for manometric readings. It was surmised but not proved that the bleeding came from this puncture wound.

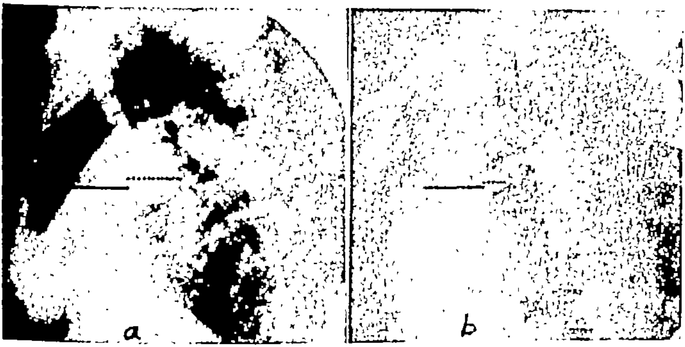

Fig. 0.—*a*. An angiogram in a 10-year-old girl, cyanotic since birth, reveals a normal sized pulmonary artery (dotted line) in relation to the aorta (unbroken line). This evidence was interpreted as supporting a diagnosis of Eisenmenger complex.

b. An angiolgram in a 12-year-old boy revealed a greatly narrowed pulmonary artery (dotted line) in relation to an oversized aorta (unbroken line). The early appearance of the dye in the aorta indicated the presence of a septal defect. Subsequent necropsy confirmed this relationship. (Same patient as shown in Fig. 2.)

Pulmonary arterial pressures at operation have ranged from 175 to 370 mm. of water. Although no arbitrary level can be set, Blalock has stated that the operation should not be done when the pulmonary pressure exceeds 300 mm. of water. In the 4-year-old child in whom the pulmonary pressure was 370 mm. of water, the systemic arterial pressure at that same moment was 110 mm. of mercury. It was reasoned that a flow of blood would therefore occur from the systemic to the pulmonary circulations, and accordingly the left subclavian artery was implanted into the left pulmonary artery with excellent improvement in cyanosis and physical activity. The mother writes that he plays normally, whereas formerly he was content simply to observe his playmates.

Improvement following operation is disclosed not only by marked improvement in appearance and physical activity, but also by marked change in the character of the blood; in one instance the number of red cells dropped from 11.4 million to 6.9 million, and the hemoglobin concentration from 188 per cent to 103 per cent. In another case, the red cells fell in number from 7.8 million to 5.5 million and the hemoglobin concentration dropped from 142 per cent to 99 per cent.

Various operative approaches have been used. At first, Blalock's anterior incision through the third interspace was employed. This has been replaced in girls by a left anterolateral approach through the third interspace to avoid conspicuously visible anterior scars and possible injury to breast tissue. In boys an anterior approach through the second interspace is now used, with division of the second and third costal cartilages. This provides an excellent exposure of the left hilum and more ready access to the left subclavian artery.

In performing the anastomosis, a longitudinal rather than a transverse incision is now made in the pulmonary artery, and the suture employed is a continuous adventitia-to-adventitia approximation in the posterior half, and a continuous intima-to-intima approximation in the anterior half of the circular anastomosis. An effort is made to interrupt completely the circular silk suture at two points, thus avoiding a complete circular suture of nonabsorbable silk which might conceivably result in a fibrous, nondistensible rim to the circular opening. It is hoped that the anastomosis will dilate as the child grows and as more blood is needed for aeration. In peripheral arteriovenous fistulas such dilatation of the anastomosis itself does occur, its extent depending upon the original size of the fistula, its duration, and its location in the vascular tree. Moderate and gradual increase in the size of the anastomosis in the Blalock procedure is probably desirable and necssary if the volume of blood passing through the anastomosis for aeration in the lungs is to increase commensurate with the increase in size and weight of the child and with the increase in total volume of blood. Unless such an increase in blood flowing through the anastomosis takes place, it seems probable that the patient will again show signs of inadequate oxygenation as bodily growth takes place.

It must be recognized that the establishment of this artificial patent ductus carries with it the same hazards as those associated inevitably with the congenitally patent ductus, namely, cardiac failure, bacterial endocarditis, and endarteritis. The latter may be controlled by antibiotic therapy, the former may be without remedy. Inasmuch as the resistance to the flow of blood through the pulmonary circuit will always be less than the resistance to the flow through the systemic capillary bed, there will be a constant tendency for more blood to be diverted through the anastomosis and therefore through the lungs and the left heart, which may lead ultimately to an overburdening of this half of the heart. It seems quite probable, therefore, that these patients will eventually succumb to the same difficulties which are associated with a patent ductus, and that their life expectancy is no greater than that of the patent ductus, perhaps even less, because of the associated anomalies of a patent interventricular septal defect, and right-sided cardiac hypertrophy. In the meantime, however, the greatly improved physical status of these unfortunate little patients is a great boon to distraught and solicitous parents.

SUMMARY

Thirty-eight patients with cyanosis have been operated upon.

In seven, thoracotomy without anastomosis was performed with five deaths. These fatalities are explained on an increased deflection of unaerated blood into the systemic circulation through the interventricular septal defect, due to the increased peripheral resistance in the pulmonary vascular bed incident to anesthesia and to the opening of the chest.

In twenty-nine patients, a systemic artery was joined to the pulmonary artery as proposed by Blalock: in two, the innominate artery was joined to the pulmonary artery with excellent results; in one, the right common carotid artery was united with the right pulmonary artery, followed by a temporary left hemiplegia; in three, the right subclavian artery was joined to the right pulmonary artery with one death (in a patient 19 months old) and with two excellent results.

In twenty-three patients, the left subclavian artery was joined to the left pulmonary artery with two deaths, and twenty-one good to excellent results. In four patients the left pulmonary artery was completely divided proximal to the anastomosis because of sharp angulation at the origin of the subclavian artery which prevented a free flow of blood through the anastomosis. Following such division, the distal pulmonary artery rose in position in the chest, the angulation was corrected, and a good flow through the anastomosis occurred.

It is suggested that the left subclavian artery is preferable to the right because of its greater length, and if angulation at its origin occurs following its anastomosis, such angulation can be corrected by complete division of the pulmonary artery proximal to the end-to-side anastomosis.

In two patients, each 9 months old, the Potts procedure of direct anastomosis between pulmonary artery and arch of aorta was performed with one excellent result and one death.

REFERENCES

1. Cutler, E. C., Levine, S. A., and Beck, C. S.: The Surgical Treatment of Mitral Stenosis, Arch. Surg. 9: 689, 1924.
2. Blalock, A., and Taussig, H. B.: Surgical Treatment of Malformations of the Heart in Which There Is Pulmonary Stenosis or Pulmonary Atresia, J. A. M. A. 128: 189, 1945.
3. Blalock, A.: The Technique of Creation of an Artificial Ductus Arteriosus in the Treatment of Pulmonic Stenosis, J. THORACIC SURG. 16: 244, 1947.
4. Blalock, A.: The Use of Shunt or By-pass Operations in the Treatment of Certain Circulatory Disorders, Including Portal Hypertension and Pulmonic Stenosis, Ann. Surg. 125: 129, 1947.
5. Holman, E.: Congenital Intracardiac Fistulae, Arch. Int. Med. 36: 516, 1925.

DISCUSSION

DR. F. D. DODRILL, Detroit.—I wish to speak about a small group of patients in whom the left subclavian artery was used for the anastomosis to the left pulmonary artery. During the last twelve operations for tetralogy of Fallot, I have used the left-sided approach, a left aortic arch being present in all cases, hoping to use the left subclavian artery. An anastomosis was carried out in eleven of these patients. In ten of the patients it was quite satisfactory, there being no angulation of the subclavian at its origin from the aorta. However, in one patient there was angulation of the subclavian artery as it arose from the aorta. Not knowing of Dr. Holman's technique, I freed up the outer portion of the aortic arch and thought that the angulation was definitely less. It is now six months since the operation, and there is good clinical response. In the one patient in whom the subclavian artery was not used, a Potts aortic-pulmonary artery procedure was carried out with good results. The youngest patient in this group was 15 months old, the oldest 22 years. In older children and adults the left subclavian artery is longer and, therefore, there is a better chance that it will reach to the pulmonary artery.

In this group in which left-sided approaches were used there was one death; a 22-year-old man died of embolism arising in the lower extremity. At autopsy there were emboli in the lungs, brain, and kidney. The anastomosis was fully patent without evidence of thrombi at the suture line. The remainder of the patients have had a good clinical response. The oxygen saturation has increased, the red blood count has returned to normal or near normal, and the tolerance to exercise has markedly increased. Previous to this time there were twenty-six operations carried out on the right side, using the right subclavian artery, but in a few of the earlier cases, the carotid artery was used. There were five deaths in this group. In two instances, however, death occurred as the chest incision was being made and before the vessels were isolated.

If the subclavian artery and a posterior approach are being used, I believe it is important not to carry the incision too high on the chest wall, as some of the collateral circulation to the arm might be sacrificed.

DR. HOWARD T. BARKLEY, Houston, Texas.—We have had only a small series of cases, but I wish to add a few words to the experiences of the essayist and discussers.

We have been impressed by the difficulty in making a definite diagnosis in these cases preoperatively. Perhaps with the use of angiograms, which we have not had available up to the present time, we can expect further aid in definite diagnosis; however, it is our feeling that in most of these cyanotic patients exploration should be carried out on the chance that some situation will be found that can be helped by anastomosis. We found one such case with a common truncus arteriosus in which the pulmonary artery was exceptionally small. We feel that this patient would have been benefited by the anastomosis of a larger vessel to the pulmonary artery, but unfortunately the patient died on the operating table. This is the only death we have had at operation. In dissecting out the pulmonary artery on the left side, we had completely occluded the blood flow to the lungs by tension at the bifurcation of the main pulmonary trunk, thus producing a complete anoxemia. This was shown to be true at autopsy; therefore, we advise great caution in dissection of the vessels in the mediastinum until the true situation can be seen.

We have preferred the posterolateral approach because of the additional working space and better visualization, and we prefer to the left-sided approach if there is no apparent contraindication. In one of our early cases, we used the right-sided approach because of a left aortic arch, expecting to use the right innominate or subclavian in a very small child. We were unable to find a pulmonary artery on the right side and had to withdraw; therefore, we have felt we would always have a better opportunity using the left side in exposing the base of the heart and finding even a small pulmonary artery, if there is one present, and perhaps being able to make some type of anastomosis rather than having to admit defeat.

DR. CLARENCE CRAFOORD, Stockholm.—I would like to make a few brief comments and show two slides. We now always try to get an anatomic diagnosis through angiocardiograms before operation. I know that the master in this field considers cardiograms not to be necessary; by information from good cardioangiograms we get, preoperatively, information as to how the pulmonary artery, the aorta, and the big vessels leaving the arch are localized and information on the size of the pulmonary artery and its branches. We perform the *cardioangiograms in children most often under general anesthesia*, either with injection in the cubital vein or, if this method does not give satisfactory results, through the heart catheter when all information at catheterization is obtained. These exact data are of importance for the planning of the operation. The following slides will demonstrate what I have now said.

(Slides.) Where there is difficulty in bridging over the gap between the subclavian *artery and the pulmonary artery when performing the end-to-side anastomoses between* these vessels, I have found it most helpful to divide the pulmonary ligament up to the lower pulmonary vein, which permits the whole hilum of the lung to be considerably elevated in a cranial direction, thus facilitating the anastomoses without tension.

DR. JULIAN JOHNSON, Philadelphia.—We have encountered two patients in whom the subclavian artery was so short that it seemed to us that it would be impossible to use it to do the Blalock operation. On the basis of experimental work in the laboratory, we felt that we could safely do a vein graft to increase the length of the subclavian artery, so that it could be anastomosed to the pulmonary artery. In both instances, we took a section of the superficial femoral vein and used it as a graft between the end of the right subclavian artery and the right pulmonary artery. Both patients obviously had functioning anastomoses with a left or right shunt. Unfortunately, one of these patients died from a pulmonary embolus, apparently having arisen at the site where the vein was taken in the superficial femoral area and having lodged in the pulmonary artery at the point of stenosis. The other patient, however, has done exceedingly well and has a loud continuous murmur. It would seem to us that when one encounters the situation of an inadequate length to the systemic vessel, that if other maneuvers are not adequate, one can safely use a vein graft to fill the gap to the pulmonary artery.

DR. ALFRED BLALOCK, Baltimore.—I want to congratulate Dr. Holman on this excellent presentation. The suggestions which he has made regarding points in operative technique are good. In this connection I would like to caution that the clamp which we devised for occluding the pulmonary artery should not be used on systemic arteries. If the clamp is applied tightly, it will crush the intima of a systemic artery.

Dr. Crafoord, I wish we felt as confident of the diagnosis in all cases as you seem to think we do. Even so expert a diagnostician as Dr. Taussig is not always certain as to the exact nature of the malformation. As an example, I have performed anastomoses on at least five patients who had a transposition of the great vessels under the assumption that we were dealing with pulmonic stenosis.

It was my impression prior to 1947 that an artificial ductus should not be created in the treatment of pulmonic stenosis if the pressure in the pulmonary artery is greater than 350 mm. of water. Subsequent experience has shown that this impression is wrong. Several months ago an artificial ductus was created in a patient in whom the pressure in the pulmonary artery was 530 mm. of water. The pulmonary artery was of good size, and the pulsations were strong. This patient has improved markedly following the operation.

In regard to the site of the incision we still use the anterior approach but feel that there is no strong objection to the posterolateral approach. We now make the incision into the chest through the second interspace instead of the third. I would like to show a few lantern slides of drawings which demonstrate the various operations which may be used. These show an end-to-side anastomosis between the subclavian branch of the innominate and the right pulmonary artery, and end-to-side anastomosis between the subclavian branch of the aorta and the pulmonary artery, and end-to-end anastomosis between the subclavian artery and the pulmonary artery, and a side-to-side anastomosis between the aorta and the pulmonary artery. *I would like to emphasize that a good end-to-end anastomosis is preferable* to a fair end-to-side one.

In conclusion, I would like to express an opinion as to the choice of operative procedure under various conditions. If the patient's aorta descends on the right instead of the left, which occurs in about 22 per cent of the cases, I think that the incision should always be made on the left and an anastomosis performed between the subclavian branch of the innominate and the side of the left pulmonary artery. When the innominate is on the left, there is rarely any difficulty in approximating its subclavian branch to the pulmonary artery. Approximately 155 of our 650 patients have had an aorta which descended on the right. When the aorta descends on the left, we vary the approach somewhat according to the age and size of the patient. In patients between the ages of 2 and 12 years, and these constitute the majority, the incision is made on the right, and the end of the subclavian branch of the innominate is usually anastomosed to the side of the right pulmonary artery. In patients who are more than 12 years of age, we usually make the incision on the left and use the subclavian branch of the aorta. This is the procedure about which Dr. Holman has spoken. The left pulmonary artery is at a slightly higher level than the right, and this aids in the approximation. In patients under 2 years of age, the choice varies. If we think that the subclavian artery is large, normally we make the incision on the right and use the subclavian branch of the innominate. If it is thought that the subclavian artery is quite small, we make the incision on the left. If the subclavian is found to be large enough, we anastomose it to the left pulmonary artery. If the subclavian appears too small, we perform a side-to-side anastomosis between the aorta and the left pulmonary artery as developed by Dr. Potts. We do not advise operation on patients under the age of 2 years unless they are doing very poorly. The important point to remember regarding the operative procedure is that one should be aware of the various methods that may be used since there is no single procedure that can be applied satisfactorily to all patients. Most of the unfortunate experiences arise as the result of a poorly developed or absent pulmonary artery. There is always a systemic artery which can be utilized.

DR. HOLMAN.—I want to thank the master for giving us the final word on this subject. We, too, have found that we could perform anastomosis with pressures in the pulmonary artery as high as 420; we have not gone higher than that.

DEVELOPMENT OF ANASTOMOSIS BETWEEN THE CORONARY VESSELS AND A TRANSPLANTED INTERNAL MAMMARY ARTERY

ARTHUR M. VINEBERG, M.SC., PH.D., M.D.C.M., MONTREAL, QUEBEC

DURING the past fifteen years many attempts have been made to augment impaired coronary circulation. Three main procedures have been described. The first of these is dependent upon the grafting of a vascular structure to the ventricular wall such as the pectoral muscle graft of Beck in 1935 or the great omental graft of O'Shaughnessy in 1937.

The second procedure employs the parietal pericardium as a source of fresh blood. Talc powder or asbestos fibers are introduced into the pericardial sac. The reaction caused by the foreign body particle stimulates the formation of granulation tissue between the visceral and parietal pericardium.

The third procedure, described by Fauteux in 1940, depends upon ligation of the vena magna cordis to increase ventricular circulation.

All three procedures have been carried out upon human cases of coronary artery disease. The first two methods bring a fresh supply of arterial blood to the ventricle through a layer of granulation tissue. In time the granulation tissue contracts into scar with resultant choking off of the newly formed blood vessels. The third procedure relies upon venous occlusion to open anastomoses between the partially thrombosed coronary arteries, arterial luminal vessels, and arterial sinusoidal vessels.

The basic objective in this work has been to supply a fresh source of arterial blood to the heart muscles. In order to do this, the left internal mammary artery has been partially removed from its normal position on the chest wall and implanted into the myocardium of the left ventricle. In this way we thought that a communication might be developed between the implanted internal mammary artery and the left coronary circulation.

METHOD

Basically, the method consists of freeing the left internal mammary artery from the chest wall for variable distances. All intercostal branches are tied and severed over the free part of the artery. The artery after being doubly ligated is cut across at its distal end. The proximal free end of the artery is drawn through a previously prepared tunnel in the anterior wall of the left ventricle where it is fixed. All operations were carried out under aseptic conditions and the animals were kept from six weeks to thirteen months. At the end of this time they were either sacrificed by bleeding or the anterior descending branch of the left coronary artery was ligated at its origin. The circumflex branch of the left coronary artery was ligated in those animals surviving an anterior descending branch interruption. After death the internal

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From the Department of Surgery, Royal Victoria Hospital and the Departments of Physiology and Experimental Surgery, McGill University.

Read at the Twenty-eighth Annual Meeting of The American Association for Thoracic Surgery, Quebec, Canada, May 31, June 1, 2, 1948.

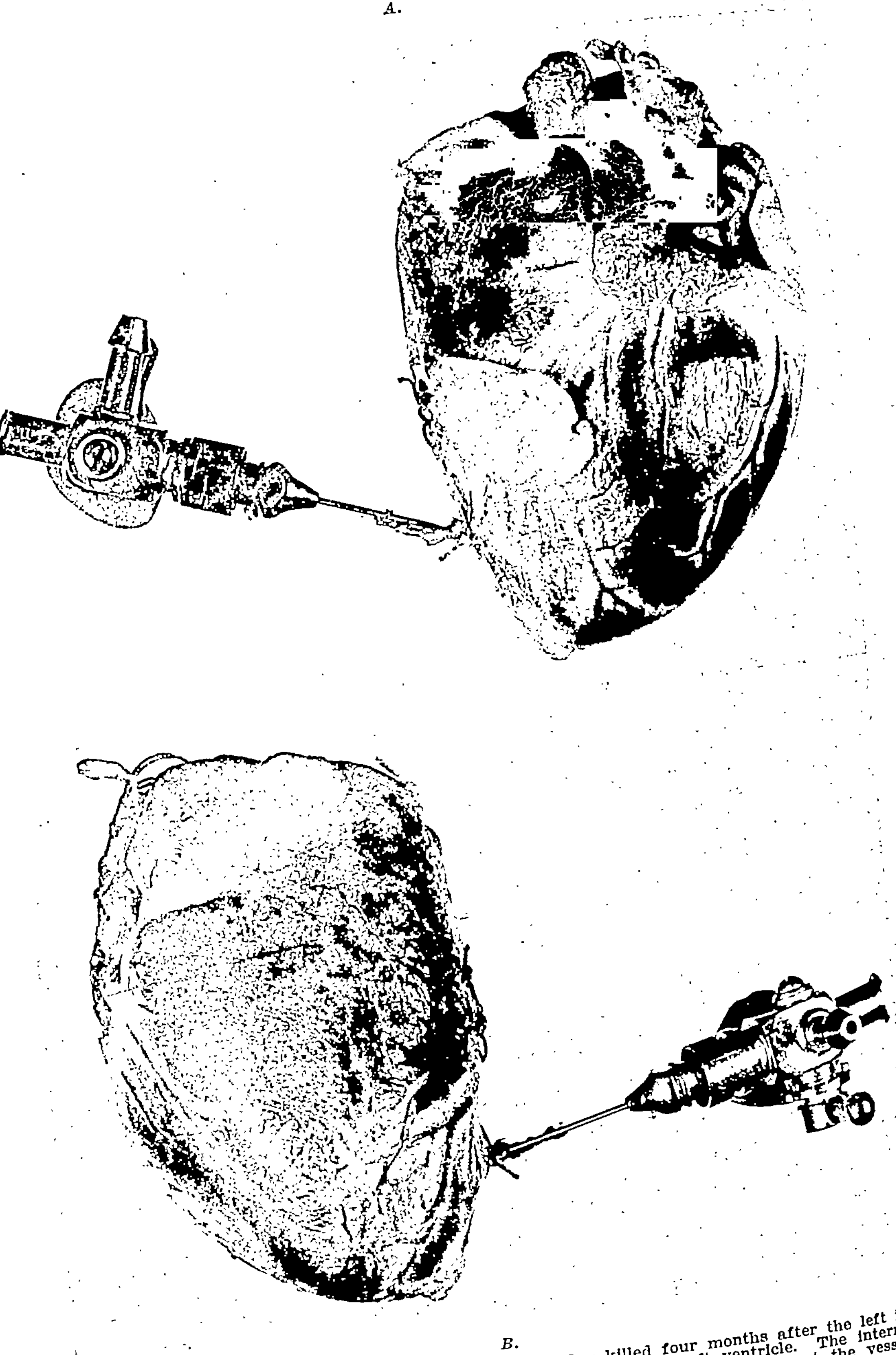
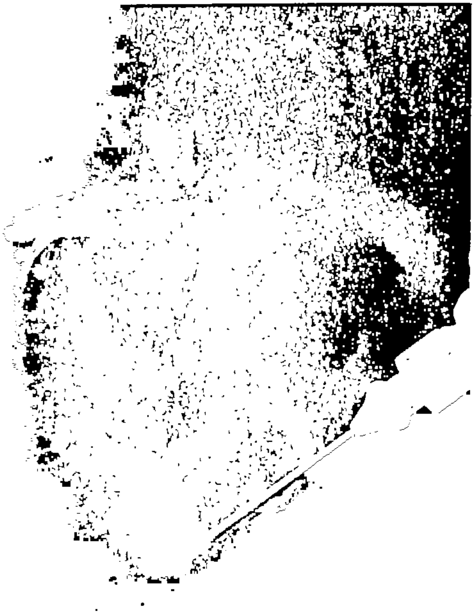


Fig. 1, *A* and *B*.—These show the heart of a dog killed four months after the left internal mammary artery had been implanted in the wall of the left ventricle. The internal mammary artery had been injected with pink Schlesinger's solution. Note that the vessels of the left ventricle only have been filled by the injection fluid.

mammary artery was cannulated and its distal end injected proximal to the heart. The Gross or Schlesinger technique of injection was employed. Certain specimens were injected with a plastic solution and a cast was made of the arterial lumina.



C.

Fig. 1, *C*.—X-ray of the left coronary tree which has been filled by injecting the left internal mammary artery four months after it was implanted into the left ventricular wall.

PROOF OF ANASTOMOSIS

The presence of anastomosis between a transplanted left internal mammary artery and the left coronary circulation has been studied by means of

(1) x-ray examination of injected specimens,

(2) serial sections taken through the site of anastomosis, and

(3) the making of a plastic cast of the arteries involved to show the nature of anastomosis.

The photographs shown in Fig. 1, *A, B, C, D, E,* and *F* represent studies made on Dog A5 in which the internal mammary artery was transplanted into the left ventricle on Feb. 4, 1946. The dog was killed on June 14, 1946, approximately four months later. The photographs shown in Fig. 1, *A,* and *B* are of the same heart after it has been injected by a pink Schlesinger solution. It should be noted that the vessels of the left ventricle only have been filled.

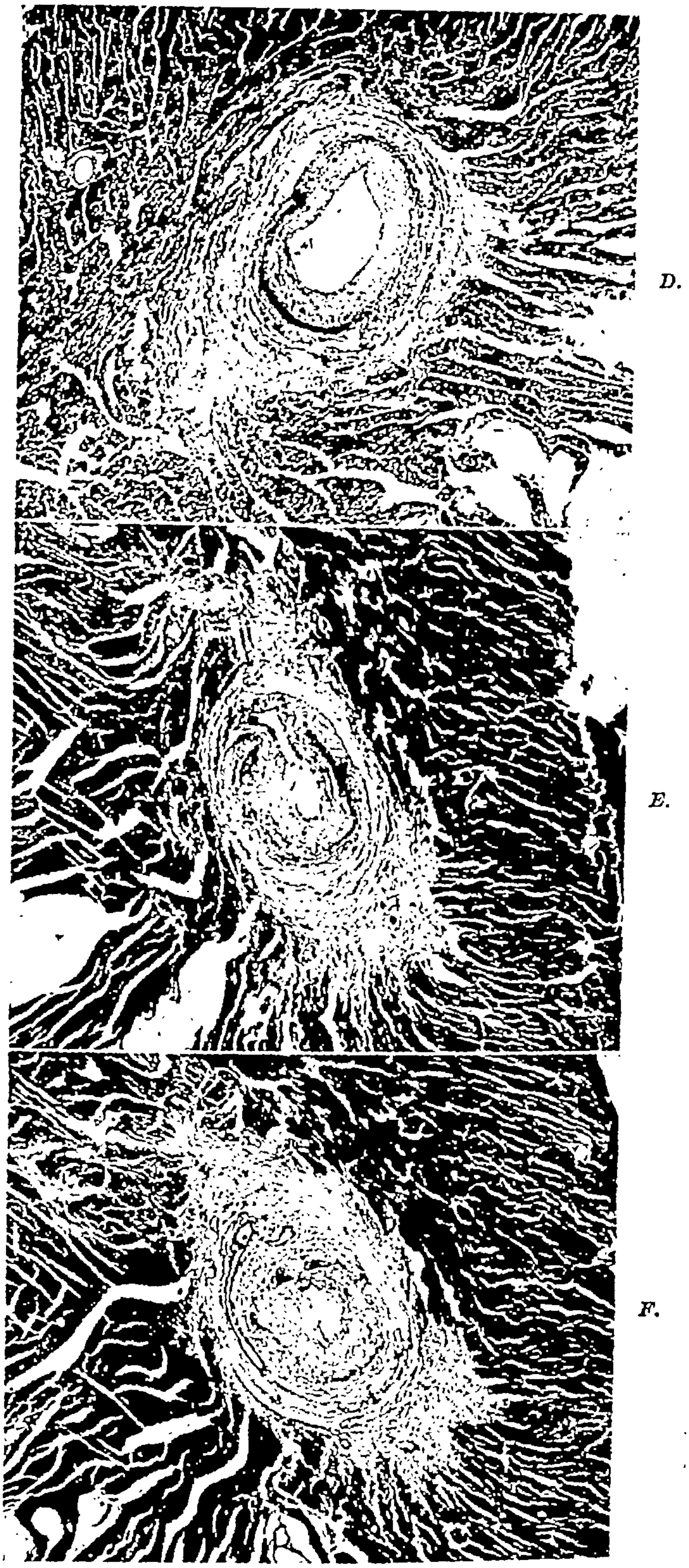


Fig. 1, *D*, *E*, and *F*.—The transplanted internal mammary artery lying within the muscle of the myocardium at the end of four months. Note that the only change to be observed is a thickening of the intima. *D*, It will be noted that in the upper portion of the section there is an indentation which is the beginning of a branch. *E* shows the internal mammary artery with the branch well developed. *F* shows a branch of the internal mammary artery lying alongside of the parent vessel.

The x-ray studies (Fig. 1, *C*) showed that the left coronary artery tree was filled by injecting the left internal mammary artery four months after its implantation into the left ventricular wall.

Serial sections (Fig. 1, *D*, *E*, and *F*) taken through the site of the internal mammary artery implantation showed:

1. In the upper portion of the section there is an indentation which is the beginning of a branch.
2. The internal mammary artery with branch well-developed.
3. A branch of internal mammary artery lying alongside of the parent vessel.

Photographs shown in Fig. 2, *A*, *B*, *C*, *D*, *E*, and *F* represent studies made on Dog A6 in which the internal mammary artery was transplanted into the left ventricular wall on Feb. 11, 1946; the dog was killed March 25, 1947, approximately thirteen months later.

Fig. 2, *A*, and *B* shows the filling of the left coronary circulation after the internal mammary artery was injected with Schlesinger solution (blue). Serial sections (Fig. 1, *C*, *D*, *E*, *F*, and *G*) show an indentation developing in the wall of the artery (internal mammary) lying within the ventricular myocardium. This indentation gradually develops, becomes larger, and finally separates into an independent branch which is seen lying alongside of the parent vessel.

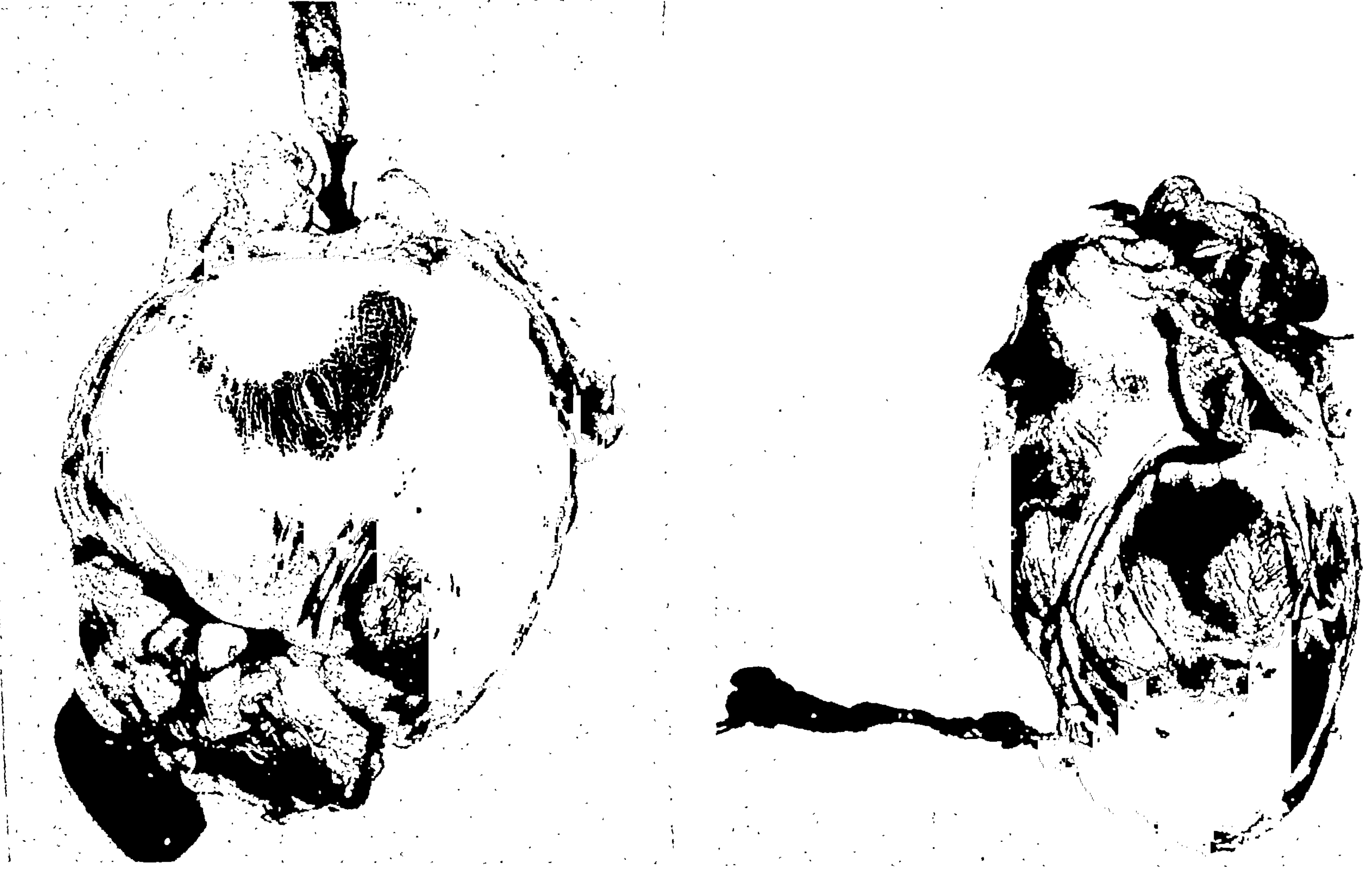
The photograph shown in Fig. 3 represents a plastic cast which was made of the internal mammary artery and the left coronary circulation on Dog A10. This animal had a left internal mammary artery transplanted into the left ventricular wall on June 21, 1946. The anterior descending branch of the left coronary vessel was ligated on April 12, 1947. The dog was killed on May 12, 1947, at which time a plastic cast was made of the internal mammary artery. It should be noted that the intercostals which had been tied off by cotton sutures failed to branch, whereas that part of the artery lying within the heart showed numerous new branches.

RESULTS (TABLE I)

Results are divided into four main groups. Division depends upon the method used to prepare the iternal mammary artery for transplantation into the left ventricular wall.

Group 1.—The internal mammary artery was freed from the sixth intercostal branch to the subclavian artery. By this means a very long piece of artery was obtained which could be implanted into the left ventricular wall without angulation. A total of thirty-nine dogs was operated upon of which fourteen survived more than one month. In this group there was not a single case of arterial anastomosis.

Group 2.—The internal mammary artery and vein were freed together from the sixth intercostal to the fourth inclusive. The total number of animals operated upon was eighteen. Those that suvived were eleven in number. There was one (9 per cent) anastomosis.



A. B.

Fig. 2, *A* and *B*.—Cannula in the left internal mammary artery thirteen months after the artery had been implanted in the wall of the left ventricle. Note that the injection fluid has flowed down the artery into the left coronary circulation and out into the pulmonary vein. It has also flowed into the chest wall. Examination of *B* demonstrates that only the left coronary vessels were injected to the complete exclusion of the vessels of the right ventricle.

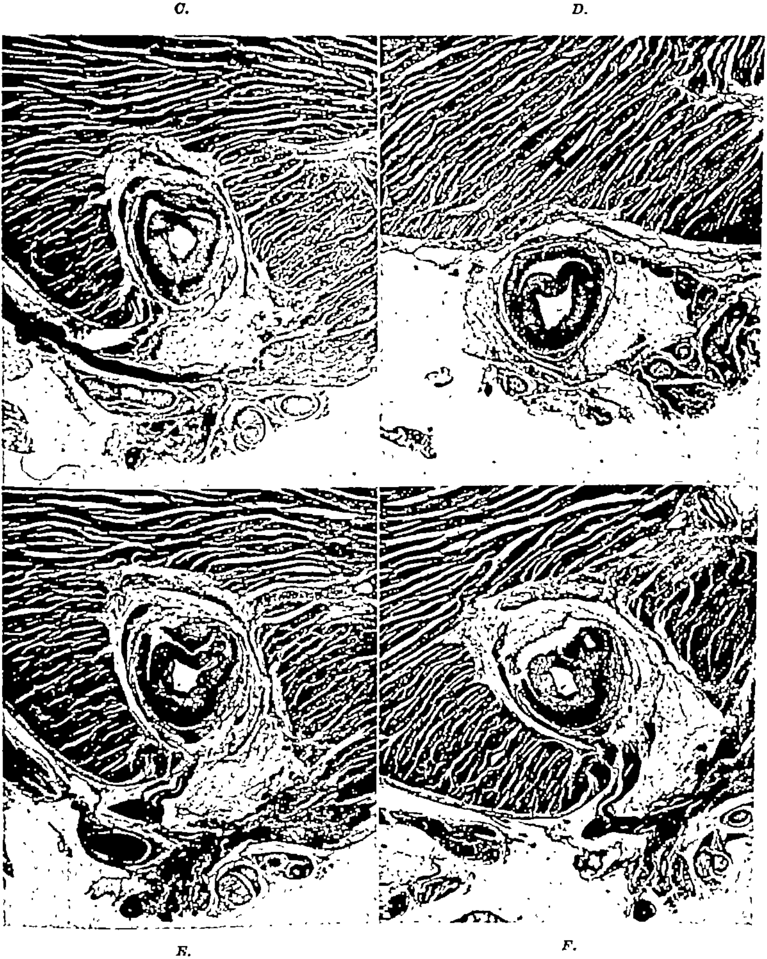


Fig. 2, *C*, *D*, *E*, and *F*.—Serial sections taken through the internal mammary artery, at the site of its implantation into the left ventricular wall (Dog A-6). In *C* there is an indentation in the arterial wall, which gradually develops into a second artery as shown in *C*, *D*, *E*, and *F*. The new artery is seen lying alongside of the parent vessel.

Group 3.—The internal mammary artery was freed from the sixth to the second intercostal arteries. The total number of dogs operated upon was thirty-one, of which fourteen survived. There were three (20 per cent) animals in which there was a proved anastomosis and one in which the anastomosis was suspected.

Group 4.—The artery was freed between the sixth and fourth intercostal vessels. In this group there were sixteen animals of which nine survived more than one month, and there was a proved anastomosis in four (44 per cent) and suspected anastomosis in two animals.

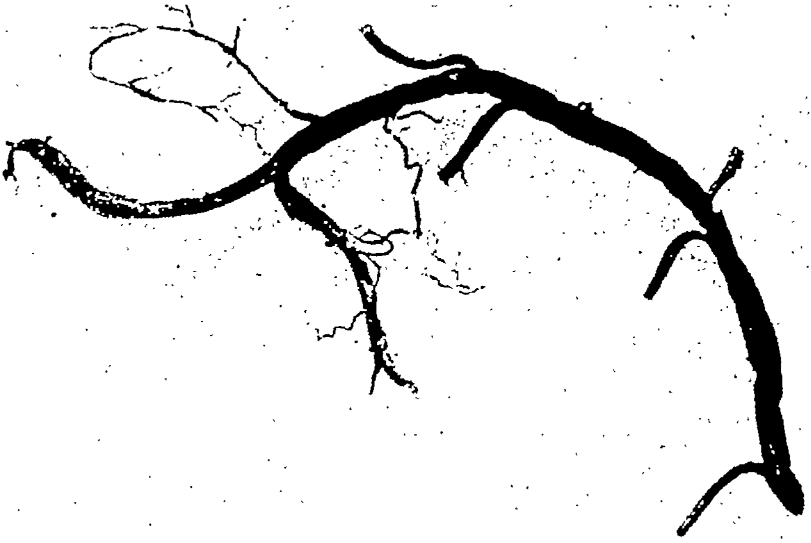


Fig. 3.—A cast has been made by injecting the internal mammary artery with a plastic substance ten and one-half months after implantation into the left ventricular wall. The small sharply cut off branches to the right are intercostals tied with cotton. The fine arborizations to the left have developed within the heart muscle.

When anastomosis occurs between the transplanted left internal mammary artery and the left ventricular vessels, there appears to be no connection between this anastomosis and the coronary vessels of the right ventricle. There is evidence to show that when this anastomosis is present it does not protect against a circumflex branch ligation. On the other hand, there is evidence to suggest that the new vessels will protect the left ventricle when the anterior descending branch of the left coronary artery is ligated at its origin. A total of twenty-nine dogs was subjected to ligation of the anterior descending branch of the left coronary artery at its origin following transplantation of the internal mammary artery into the left ventricular wall. Of these, twenty-four died within twenty-four hours of ligation and there were five which survived. It should be noted that of the five survivors there were three in which there was no anastomosis. All three showed massive ventricular wall infarction. Two of these showed residual branches of the anterior descending artery which were not included in the ligature. One survived in spite of infarction and a ligature properly placed to include all branches. Two of the five showed definite anastomosis with the left coronary circulation and no evidence of a ventricular wall infarction.

TABLE I. RESULT OF TRANSPLANTATION OF INTERNAL MAMMARY ARTERY INTO WALL OF LEFT VENTRICLE

DISTANCE OVER WHICH INTERNAL MAMMARY ARTERY FREED	NO. OF DOGS	LIVED MORE THAN ONE MONTH	PROVED ANASTOMOSIS	SUSPECTED ANASTOMOSIS	PATENCY OF ARTERY						REVASCULARIZATION OF CHEST WALL OR PERICARDIUM
					MORE THAN ONE MONTH			LESS THAN ONE MONTH			
					THROUGHOUT	TO SCAR	BLOCKED	THROUGHOUT	TO SCAR	BLOCKED	
Group 1 6th intercostal to subclavian	39	14	0	0	1	5	4	13	2	3	10
Group 2 6th to 3rd intercostal with vein	18	11	1 (9%)	0	1	9	0	1	0	0	Not recorded
Group 3 6th to 2nd intercostal	31	15	3 (20%)	1	3	7	0	5	1	2	9
Group 4 6th to 4th intercostal	16	0	4 (44%)	2	1	3	0	3	0	0	4
Total	104	49	8 (16%)	3 (6%)	6 (12%)	24 (49%)	4 (8%)	22	3	5	

DISCUSSION

Certain facts have been established which are difficult to explain. It is not clear what the mechanism is which permits an artery with one end closed to remain patent for many weeks and even months. Nor is there an explanation for the tendency of a transplanted internal mammary artery to form new branches when placed in a new vascular bed. In practically all instances when the artery was occluded by scar or a thrombus within the heart, new branches were sent out to the pericardium and chest wall. In many instances the artery reformed a completely new set of intercostal vessels. There is evidence that angulation of the artery plays an important part in its occlusion and that traumatization of the artery results in thrombus formation which might be diminished by the use of anticoagulants.

Certain technical difficulties which have been encountered in the dog should not be met with in man. The proximity of the human heart to the chest wall, and thus to the internal mammary artery, makes the possibility of angulation less likely. The mediastinum is nonexistent in the dog which prevents an extrapleural approach to the artery which will be possible in man. The extrapleural approach should materially diminish scarring of the artery. The accumulation of intrapleural fluid is practically impossible to control in dogs. Control of pleural fluid and the use of anticoagulants present no great problem in the human being. In the dog the internal mammary artery has been transplanted into a myocardium where there was a good arterial pressure. In man suffering from coronary artery disease, this would not be true. For these reasons it is thought that transplantation of the internal mammary artery into the wall of the left ventricle, in human cases of coronary artery disease, would have a better chance of forming a new vascular bed in man than in the dog.

CONCLUSION

The left internal mammary artery, after implantation into the left ventricular wall, formed a communication with the circulation of the left coronary vessels.

REFERENCES

1. Beck, C. S.: Ann. Surg. 102: 801, 1935.
2. O'Shaughnessy, L.: Lancet 1: 185, 1937.
3. Fauteux, M.: Surg., Gynec. & Obst. 71: 151, 1940.

DISCUSSION

DR. SAMUEL ALCOTT THOMPSON, New York.—For approximately nine years we have been using a form of surgical treatment for patients having coronary disease and angina. We consider this a form of rehabilitation rather than cure of the patient. We use U.S.P. talcum powder inside the pericardial sac, which produces two results: establishment of pericardial adhesions and myocardial hyperemia. The myocardial hyperemia is profuse and prolonged. It is likely that a form of talcum powder granuloma is produced which lasts for many years, and this is characterized by increased vascularity and hyperemia. This is a reversal of the myocardial ischemia which occurs in coronary artery disease.

In a series of thirty-six seriously handicapped patients, six have died. Of the remaining patients, 85 per cent are improved, and these results are classified as good or excellent. In four patients the results were poor. Eight patients have been completely relieved of their angina and consider themselves to be practically normal. The criteria of rehabilitation are first, relief of anginal pain; second, an increase in the exercise tolerance; third, the ability to take care of their daily needs so that moving about and travelling is possible, and fourth, a return to their former, or at least some gainful, occupation.

The need for rehabilitation of such cases becomes apparent from a study of the vital statistics. In 1945, the total death rate in the United States was approximately one and one-half million; almost 30 per cent of these were cardiac deaths, more than 400,000. Of the cardiac deaths, over 130,000, or approximately 10 per cent of the total death rate, were deaths from coronary disease. It is likely that a large percentage of this group was incapacitated to some degree before death.

This is a simple method of treating such cases. We do not believe it leads to scar tissue or constrictive pericarditis. The patients are checked for this at intervals by measuring the venous pressure, and in none of the patients has the venous pressure gone above its preoperative level. If such a condition were going to develop it seems that it would have developed in nine years.

DR. ALFRED BLALOCK, Baltimore.—I do not think that I would have the temerity to discuss this paper if Dr. Claude Beck, who has performed such monumental work on the blood supply of the heart, were here. As some of you know, Dr. Beck and his associates have reported recently on experiments in which one of the systemic arteries was anastomosed to the coronary sinus. Dr. T. N. P. Johns and I performed similar experiments, as have others, and I would like to speak briefly of these. In some of these experiments the proximal end of the divided subclavian artery was anastomosed to the side of the coronary sinus and in other experiments the proximal end of the carotid was anastomosed to the divided end of the coronary sinus. The purpose, of course, was to try to cause a retrograde flow. In the experiments in which an end-to-side anastomosis was performed, most of the flow of blood went directly into the right auricle. In the experiments in which an end-to-end anastomosis was performed the immediate mortality was quite high and the incidence of thrombosis of the anastomotic site in those that survived was quite high. I wish to show lantern slides of the autopsy findings in three experiments in which survival occurred and the anastomosis remained patent. The coronary sinus becomes markedly dilated and thickened. We are unable to say whether retrograde flow through the capillaries occurred.

The point I wish to make is that this is a highly dangerous operation even in the experimental animal and that the incidence of thrombosis in the experimental animal is quite high. When one considers that the average length of life in patients who survive the first attack of coronary occlusion is approximately five years, I think that one should be very reluctant to use such an operative procedure. Only yesterday Dr. Churchill and I took a long walk with a surgical colleague who had had his first episode of coronary occlusion twenty years ago and there have been repeated episodes since then. I think that both Dr. Churchill and I were more exhausted at the end of this walk than was our surgical colleague. I do feel, however, that it is very important to continue to carry out experiments on attempts to increase the blood supply of the heart.

DR. F. R. MAUTZ, Cleveland.—I have enjoyed Dr. Vineberg's paper very much, and I cannot refrain from making a few remarks concerning my own experiences while working with Dr. Beck on the original idea of producing new arterial anastomoses. It has now been well established that new arterial anastomoses between a coronary artery and an extracoronary artery can be produced by man. When first formed these vessels are small, of 100 micra or less in diameter, and therefore they cannot carry very much blood. However, if there is slowly progressive occlusion of the coronary artery, then these collaterals increase in size. However, the first channels to enlarge are the pre-existing anastomoses between the adjacent coronary arteries. We have seen instances in the experimental animals where these vessels have increased one hundred times in cross section. When both coronary arteries are slowly and progressively obliterated it is then that the extracoronary anastomoses becomes more significant. The heart can run on perhaps less than one-third of the total available coronary arterial capacity, of course with some restriction of activity. So we might say that the arterial collaterals prefer to follow the shortest detour around an obstruction, and I believe there is much to be learned about the factors that cause these arterial collaterals to enlarge once they are formed. We have observed one fact that may offer a clue. When after ligation of a coronary artery branch, infarction in the area distal to the branch is almost complete, then no enlargement of collaterals takes place no matter how long the wait. If, however, there is surviving myocardium in the area supplied by the artery, then collateral channels enlarge to an amazing degree, that is, roughly, proportional to the amount of surviving muscle and may, as I have said, amount to one or two hundred times the cross section of the pre-existing collateral channels. Teleologically, it might be considered that the demand for blood determines the ultimate degree of enlargement of the collateral channels. I think it would be best to say that there are probably metabolic factors in the partially ischemic zone of muscle that exert a profound influence upon the adjacent collateral arterial channels. I think there are great unexplored areas in metabolism of partially ischemic tissue, and Goldblatt's work on the kidney is a brilliant example of such an altered metabolism.

These little collateral arterial channels that man can now make, in addition to those that are already there, may seem of little or no functional value to the physiologist. When we find better ways of aiding them to grow, that will be of the greatest significance.

DR. EMILE HOLMAN, San Francisco.—May I express great skepticism that anyone will ever be able to convert a vein into an artery. Mont Reid made an attempt to reverse the circulation in the kidney but it resulted only in a fibrotic and functionless kidney.

DR. ARTHUR M. VINEBERG, Montreal.—These people have a very slim margin. The patients one would operate on are those who are no longer enjoying life; none of them would be able to take a long walk twenty years later. Many are totally incapacitated. In the surgical cardiac clinic at the Royal Victoria Hospital, we have had many cases with the coronary arteries practically occluded in which there was a very small stream of blood supplying the ventricle. Simple ligation of the great cardiac vein involves slight tipping of the ventricle, and the pushing of the auricle to one side. When this is done, we have seen the blood pressure drop rapidly to dangerously low levels.

I do not see how anastomosis can be made to the coronary sinus in its present position, without great harm to the patient. If we are going to operate on these people we have to do so quickly and by a simple procedure. We are not ready to go ahead with human patients as yet, but this operation is extremely simple. I would like to show one slide to show how the artery lies in position within the ventricular muscle.

COMPLETE FAILURE OF STERNAL FUSION WITH HERNIATION OF PERICARDIUM

Report of a Case Corrected Surgically in Infancy

Herbert C. Maier, M.D., New York, N. Y., and Frank Bortone, M.D.,
Jersey City, N. J.

EXTENSIVE malformations of the sternum which are of clinical significance in the neonatal period are very rare. Minor congenital anatomic variations are occasionally found. Complete failure of sternal fusion is usually associated with other serious anomalies, such as ectopia cordis, which may be incompatible with life. We are reporting a case of extensive maldevelopment of the sternum associated with protrusion of a part of the pericardium through the thoracic wall defect. Surgical correction of the abnormality was successfully accomplished. This case demonstrates the importance of surgical intervention shortly after birth if a normal thoracic cage is to be attained.

An extensive study of the development of the sternum from both the ontogenic and phylogenic standpoint has been made by Hanson,[1] and his conclusions have been most widely accepted. According to him the sternum first arises as two laterally situated sternal bands independent of the ribs (Fig. 1). These sternal bands are already present in the 6-week-old embryo. At the cephalad end a single median anterior rudiment which is intimately associated with the shoulder girdle also develops. Gradually there is approximation of the sternal bands with the ventrally growing tips of the ribs. Simultaneously the two sternal bands fuse with each other. The fusion of the sternal bands is usually complete by the ninth week of embryonic life. There is also concurrent union of the sternal bands with the anterior sternal rudiment. Subsequently transverse divisions of the cartilaginous sternum result in a number of sternebrae. These lines of division or sutures always occur opposite the ends of each pair of ribs. Ossification of these intercostal sternebrae occurs with the appearance of one or more centers for each segment. At birth the sternum is cartilaginous except for small areas of ossification.

CASE REPORT

A. L., a female infant, was delivered at the Margaret Hague Maternity Hospital on June 24, 1948.* The birth weight was 3,250 grams. The baby cried spontaneously, and respiration and circulation seemed normal. The physical findings were normal except for the thoracic abnormality. When the infant cried there was bulging of intrathoracic structures through a defect in the midline of the anterior aspect of the thoracic cage. On palpation complete lack of fusion of the two lateral components of the sternum was evident. There was but slight separation of the caudal ends, whereas the upper ends of the sternum were about 1.5 cm. apart. As a result there was an increase in the width of the upper portion of the thorax, the chest having a contour more like a cylinder than a truncated cone. The sternocleidomastoid muscles

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From the B. S. Pollak Hospital for Chest Diseases, Jersey City, N. J.

Read at the Twenty-ninth Annual Meeting of The American Association for Thoracic Surgery, New Orleans, La., March 29-31, 1949.

*Referred to us through the courtesy of Dr. Samuel A. Cosgrove.

assumed an almost vertical position because the inner ends of the clavicles were displaced laterally to a considerable degree (Fig. 2). The ribs ends had apparently fused with the lateral sternal bands in a normal manner. Cardiac pulsation was visible and could be readily felt

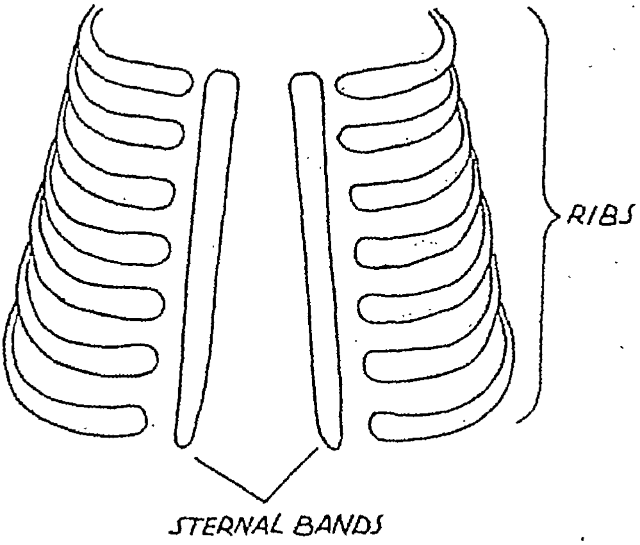

Fig. 1.—Diagrammatic presentation of sternal development in the 6-week-old embryo. There are two sternal bands which have not yet fused with the anterior ends of the ribs.

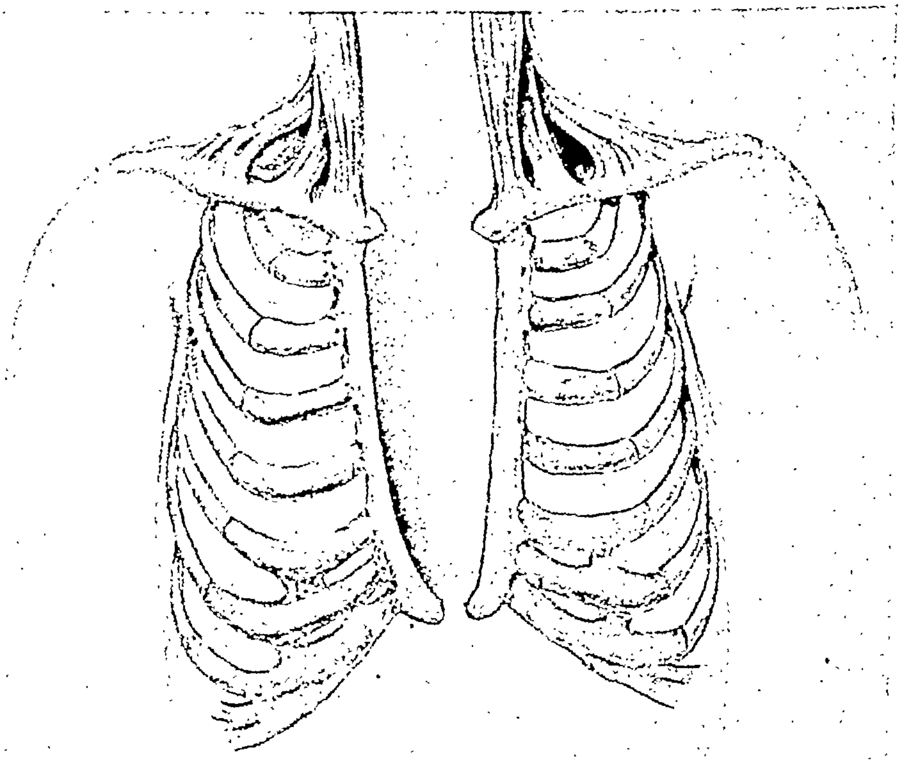

Fig. 2.—Type of sternal maldevelopment present in reported case. The sternal bands are completely separated. A wide gap is present between the inner ends of the clavicles.

just beneath the skin in the lower part of the sternal defect. There was alternating retraction and bulging of the soft tissues through the sternal gap with inspiration and expiration (Fig. 3). These movements were quite marked when the infant cried or strained. There was no cyanosis or other obvious evidence of circulatory disturbance associated with the paradoxical motion of the thoracic wall at the site of the defect. There was no clinical evidence of congenital heart disease.

The only other abnormality noted was a midline defect of the derma extending upward from the umbilicus for a distance of 2 cm. Its appearance resembled that of a healed linear scar. No umbilical hernia was evident.

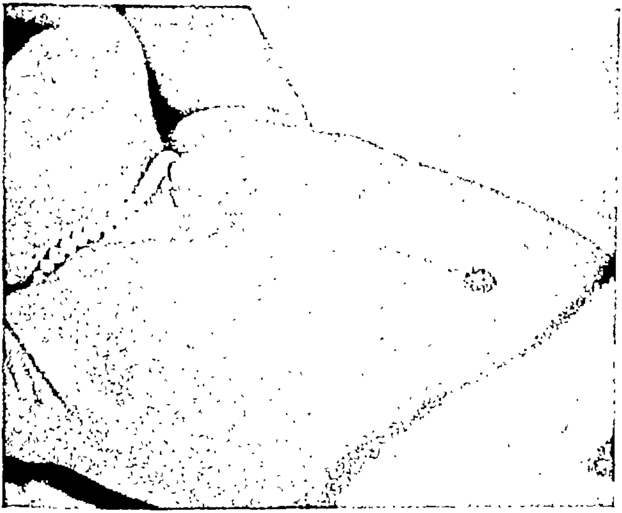

Fig. 3.—Photograph of infant at 2 weeks of age. Sternal defect indicated by retraction of chest wall in midline on deep inspiration.

Roentgenograms of the chest showed slight widening of the upper part of the thorax and of the mediastinal shadow, and elevation of the diaphragm (Fig. 4). The lung fields were clear. The clavicles appeared to be normal but retracted laterally. It was not possible to demonstrate the sternal defect itself since the sternum at birth is still almost entirely cartilaginous. The lateral view on deep inspiration revealed a marked retraction of the soft tissues of the anterior chest wall with posterior displacement of the trachea.

Operation was recommended when the infant was seen at the age of 2 weeks, but the procedure was not undertaken at once. We did not appreciate at the time the error that we were making in delaying operation. When first seen the sternal bands could almost be brought together in the midline by lateral compression of the thoracic cage. This maneuver did not cause any respiratory or other obvious embarrassment to the infant. Four weeks later, however, the thoracic cage was less flexible and the upper part of the defect wider, so that lateral compression no longer brought the edges of the sternal bands together with ease. The advisability of correcting the deformity without further delay was then very obvious.

The operation was performed on Aug. 11, 1948. Cyclopropane anesthesia was given, but the breathing was not satisfactory until the sternal bands could be brought together. Prior to that time the defect permitted so much paradoxical motion that the ventilation of the lungs was inadequate. With a closed anesthesia system the infant's inspiratory effort tended to suck in the soft tissues at the site of the defect rather than satisfactorily aerate the lungs.

A midline incision was made from the lower cervical region to the epigastrium. After incision of the subcutaneous tissues a thin-walled sac containing clear fluid was encountered in the lower half of the wound. This sac was the pericardium which not only protruded through the sternal defect but also extended superficial to the thoracic cage and pectoral muscle on the left side. The heart itself did not protrude through the sternal defect except very slightly when the infant strained. The pericardium might be described as having a large outpouching anteriorly with an associated increase in the amount of pericardial fluid (Fig. 5). The thymus bulged into the upper part of the wound but appeared otherwise normal. The lungs were not visualized, and neither pleural cavity was entered during the operation.

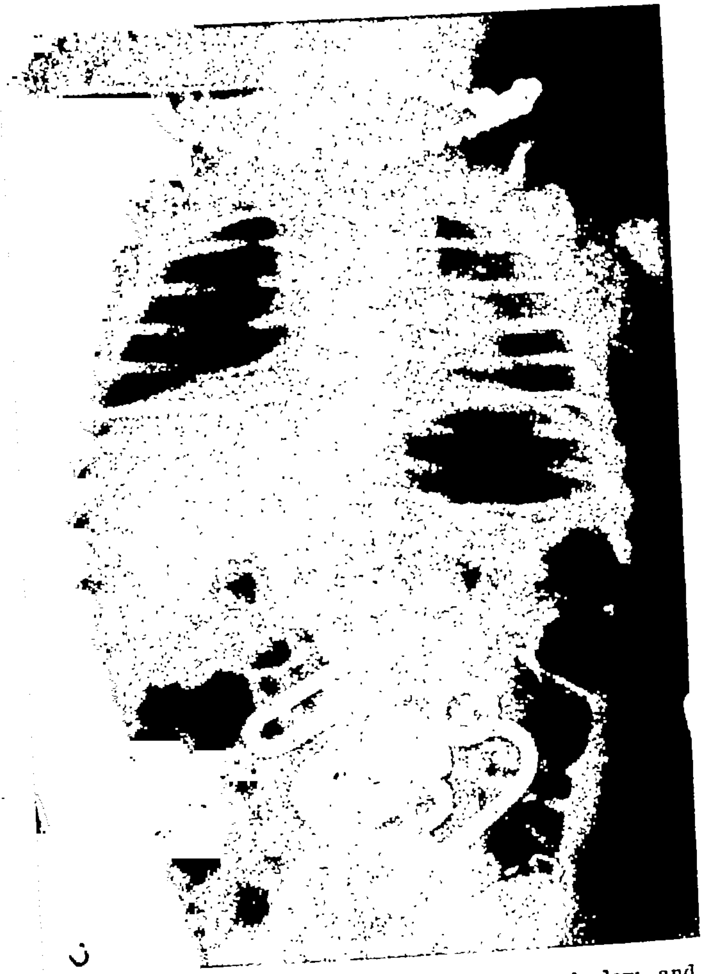

Fig. 4.—Preoperative roentgenogram; note wide mediastinal shadow and high position of diaphragm.

The herniated portion of pericardium was dissected from the subcutaneous fat, outer aspect of chest wall, and the edges of the sternal bands. The pericardium was opened during the dissection. Although there was a redundant portion of the pericardium, slight overlapping of the edges of the pericardial incision during its closure eliminated most of the excess. The thymus could be readily held within the thoracic cage. It was then possible by means of sutures to bring the sternal bands together without any other structures protruding between them. Since each sternal band was curved inward at its caudal end, the lower ends abutted on each other before the upper ends came together when traction was made with sutures.

Therefore, the cartilaginous part of the sternal bands on each side was divided transversely at the level of the fourth interspace so that the inward curve at the caudal end could be eliminated (*Fig. 6*). In so doing, care was taken to avoid complete division of the perichondrium laterally which would have interrupted the continuity of the sternum.

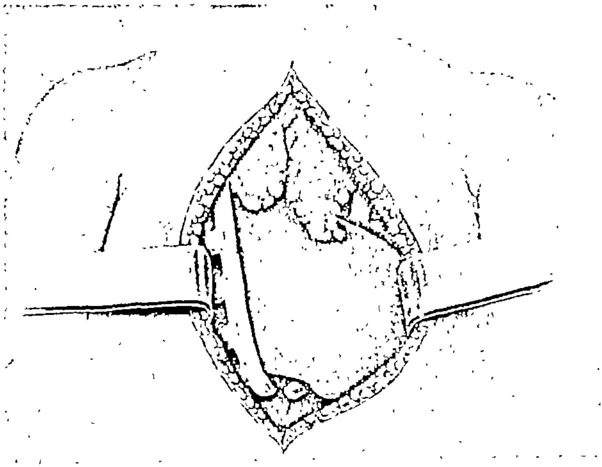

Fig. 5.—Operative findings. The herniated, redundant pericardium extends superficial to the left half of the sternum. Thymus is seen in the upper part of the incision.

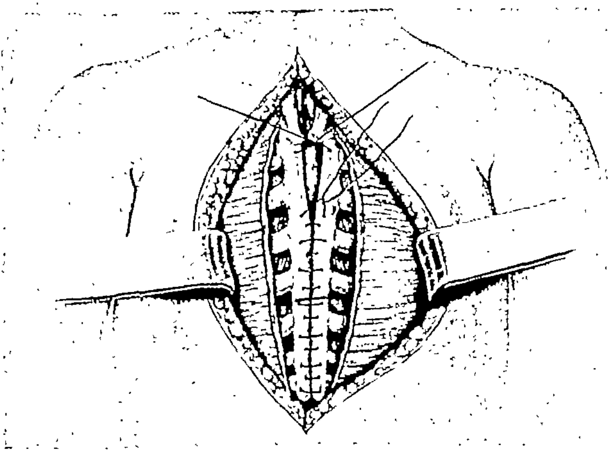

Fig. 6.—Operative procedure. The pericardium and thymus are now within the thorax, and the two sternal bands are being brought together with interrupted sutures. A partial transverse division of the sternal cartilage at the level of the fourth interspace has aided alignment.

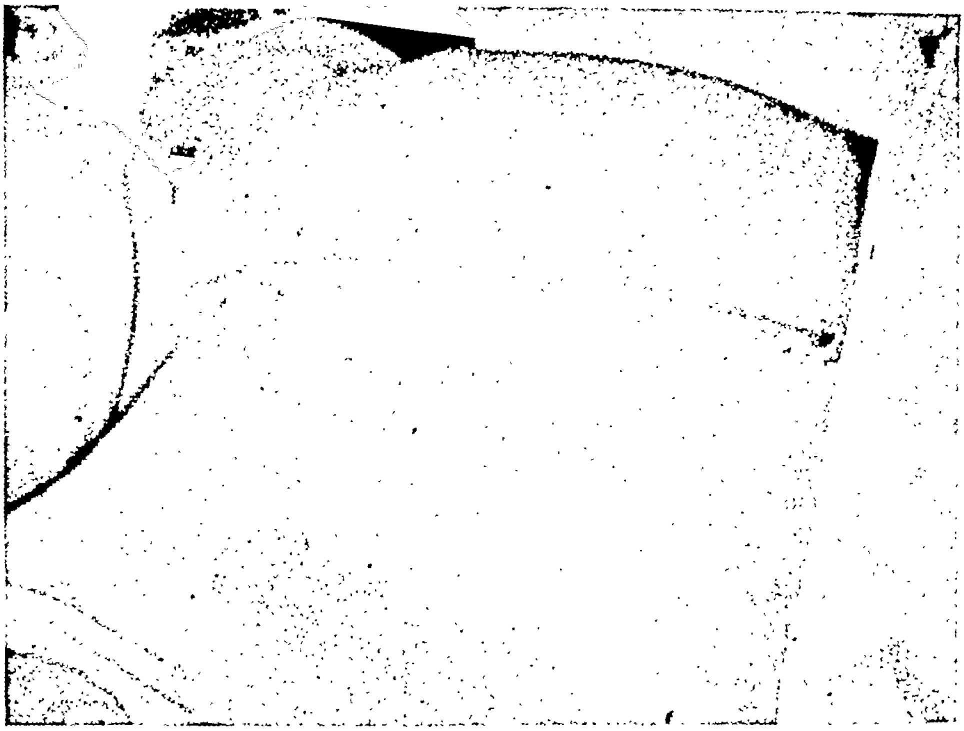

Fig. 7.—Photograph of infant two weeks postoperative. Deformity has been corrected.

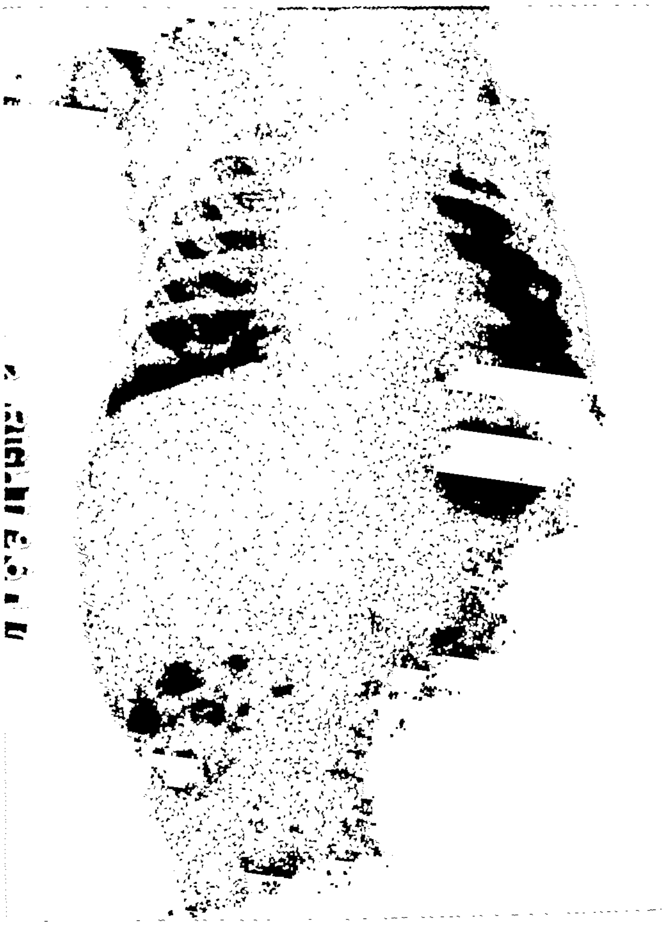

Fig. 8.—Postoperative roentgenogram. Contour of thoracic cage is now normal.

The two sternal bands covered by perichondrium were brought together and held in the midline with a series of interrupted silk sutures. The first few sutures of 00 silk were tied with some tension which, however, was relieved by additional sutures. The stitches were inserted through the middle of the sternal band on each side. Thus, perichondrium was brought in opposition to perichondrium. A satisfactory closure was obtained. The pectoral fascia was brought together with very fine silk in the midline as an additional layer. The skin, which was slightly redundant, was closed with interrupted silk. The baby's condition was good throughout the operative procedure.

The postoperative course was uneventful. No respiratory or circulatory difficulties arose. The temperature was normal on the second postoperative day. The wound healed by primary union. No separation of the sternal components occurred at any time following the operation. Roentgenogram of the chest revealed no abnormal findings. The contour of the thoracic cage is normal (Figs. 7 and 8). The baby was developing well when seen at 8 months of age.

DISCUSSION

After observing the changes which occurred in the thoracic cage of this infant between the second and sixth week after birth, we feel certain in retrospect that the operative procedure should have been performed at an earlier date. At 2 weeks of age the lateral components of the sternum could be brought together rather easily by gentle manual compression of the shoulders toward each other anteriorly so as to bring the inner ends of the clavicles together. This was no longer possible when the operation was performed at 7 weeks of age. The shape of the defect had also changed by this time. At birth the width of the gap between the upper end of the lateral components of the sternum was only slightly greater than the width of the gap at the lower end. By the sixth week, however, the upper ends were more widely separated, whereas the lower ends were perhaps slightly closer together so as to produce a V-shaped defect. It seems that the weight of the shoulder girdle transmitted through the clavicles accounted for this change. The normal intrauterine position with the shoulders rotated forward across the chest probably eliminates much traction on the lateral parts of the nonfused sternum prior to delivery. After birth, however, the infant was lying on her back most of the time, and such a position would tend to increase the separation.

Prior to operation we were concerned over the effect upon the heart, great vessels, and air passages of bringing the sternal edges together. Subsequent developments showed that in this particular case the intrathoracic structures accommodated readily to the correction of the thoracic cage defect.

A thorough review of the literature on cleft sternum and ectopia cordis was made by Greig.[3] The extensive bibliography which that article contains lists the references on cleft sternum appearing before 1926. He analyzed 39 reported cases of cleft sternum in which clinical data were available in more or less detail. In 20 of these cases varying degrees of nonfusion of the component parts of the sternum were present without cardiac displacement. In an additional 19 cases cleft sternum was associated with ectopia cordis. There were 15 further cases of ectopia cordis but without cleft sternum; in 13 there was abdominal ectopia cordis, while in the remaining 2 cases cervical ectopia was present. A few instances of prolonged survival with an intra-abdominal heart are on record. No patient with cleft sternum associated with ectopia cordis has lived for more than a few weeks.

Since the sternum may be entirely absent without a true ectopia cordis, it is obvious that nonfusion of the sternum is not necessarily related to the displaced position of the heart. In cases of an antethoracic position of the heart, however, a defect of the sternum must also be present. In some of these there may be only a relatively small opening in the sternum through which the great vessels pass. There is frequently no skin and no parietal pericardium over the exposed heart. In our case there was herniation of a redundant pericardium through the sternal defect. This factor in itself would have prevented fusion of the lower part of the sternal bands.

Nonfusion of the sternal bands may erroneously be described as absence of the sternum. If the sternum is truly absent, the inner ends of the cartilages would not be joined to each other by a cartilaginous bar, since the latter is a part of the sternal anlage. Only post-mortem or operative examination can distinguish definitely between absence of sternum and nonfusion of sternal bands in infancy.

We have been unable to find a report in the literature of successful correction of complete failure of sternal fusion in infancy. There are only a relatively small number of cases of complete fissure of the sternum recorded. In most instances death occurred shortly after birth. A few patients survived for many years, but in most such cases there was very little separation of the two lateral components of the sternum, and usually little more than a fissure was present. Of the very few adults with some separation of the two halves of the sternum, the degree of cardiorespiratory impairment varied from slight to moderate.

Burton[1] reported two cases of congenital nonfusion of the greater portion of the sternum. Operative intervention was undertaken at the age of 12 weeks in one case, whereas the other child was 12 years old at the time of the operation. No attempt was made to bring the edges of the defect together, but a free graft of cartilage was inserted into the defect. A segment of several cartilages comprising the costal arch was utilized as the graft. The procedures were undertaken in order to give protection to the heart, which was covered only by skin and subcutaneous tissue in the lower part of the defect. Only a fair cosmetic result was obtained. Although the author calls the condition one of ectopia cordis, his patients seemed to have sternal defects primarily.

SUMMARY

Complete failure of sternal fusion with a defect extending the entire length of the anterior thorax is a very rare occurrence. Such a congenital maldevelopment of the sternum may be associated with ectopia cordis. Due to the lack of a rigid thoracic cage at the site of the sternal defect, considerable paradoxical motion may occur with resultant respiratory and cardiocirculatory difficulty. If only a partial cleft sternum or a narrow sternal fissure is present, symptoms may be slight or absent.

The embryological development of the sternum is briefly reviewed. A case of complete lack of fusion of the entire length of the sternum with herniation of the pericardium is reported. This is apparently the first case reported in

which such a congenital defect was successfully corrected by surgery in infancy. The importance of performing the operation very shortly after birth is well illustrated by our case. The relationship between cleft sternum and ectopia cordis is discussed briefly.

REFERENCES

1. Burton, J. F.: Method of Correction of Ectopia Cordis. Two Cases, Arch. Surg. 54: 79, 1947.
2. Hanson, F. B.: The Ontogeny and Phylogeny of the Sternum, Am. J. Anat. 26: 41, 1919.
3. Greig, D. M.: Cleft Sternum and Ectopia Cordis, Edinburgh M. J. 33: 480, 1926.

DISCUSSION

DR. KARL KLASSEN, Columbus, Ohio.—On May 9, 1948, we performed a successful surgical repair of a cleft sternum with partial ectopia cordis on a 4-hour-old twin infant weighing 4½ pounds. We would like to present a short motion picture which illustrates several points brought out by Dr. Maier. (Motion picture.)

There is marked separation of the sternal plates with protrusion of the pericardium. The coronary vessel can be seen through the skin defect. X-ray films taken before operation show complete absence of ossification in the sternum, which was present in the normal twin. A T-shaped incision was used with resection of redundant and necrotic skin over the pericardium. Repair was made similarly to the method described by Dr. Maier. Approximation of the cartilaginous plates was accomplished without difficulty. At 2 weeks this infant appears to be normal.

The boy did well until the age of 8 months, when there again appeared separation of the sternal plates. Ossification in the sternum was still absent. Because of cardiac arrhythmia and apparent pain on movement, we performed a second operation on Jan. 24, 1949. The medial edges of the cartilaginous plates were exposed, the perichondrium and irregular cartilage removed and four tantalum pegs inserted into the substance of the sternal plates, following which silk sutures were used to approximate the two portions of the sternum. There was no change in the baby's pulse. On completion of the operation the infant appeared in good condition; however, *when he was transferred to his bed, he died suddenly.*

Autopsy showed a normal infant. There was no cardiac abnormality.

DR. MAIER.—Of course we do not know about the final development of the sternum in this child. When seen at the age of 8 months the external appearance was normal, and a firm structure without fissure was present. We do not, as yet, have roentgen evidence of ossification.

ANGIOCARDIOGRAPHY AND AORTOGRAPHY IN THE DIAGNOSIS OF CONGENITAL CARDIOVASCULAR LESIONS

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THE rapidly expanding scope of corrective surgery in congenital cardiovascular disease has emphasized the necessity for precise diagnosis. The contributions of many, but Gross and Hubbard,[1] Blalock and Taussig,[2] and Crafoord and Nylin[3] in particular, have in a very short period revolutionized the attitude of the entire profession in regard to these lesions. Fortunately, these patients are no longer crudely classified on the basis of blueness or a poorly described murmur and forgotten. Today they are salvaged, many times at the remotest levels of practice, and referred for evaluation and treatment.

Since at present the surgery of these defects is limited to definite types of deformity, and since the margin of safety is probably less in this category, particularly if the operation does not achieve correction, than in any other group of patients, the concept of an exploratory operation, valid as it is in other procedures, is rarely defensible.

As those experienced in the management of these cases known, a great many, probably the majority, can be confidently diagnosed by simple examination and fluoroscopy. There is, however, a very significant borderline group in which more exhaustive studies are necessary. Physiologic studies, such as cardiac catheterization, measurements of pulmonary capillary flow, oxygen consumption studies before and after exercise, and oximetry are of the utmost value. These studies, particularly cardiac catheterization as applied by Cournand and Ranges[4] and Bing and associates,[5] have been of the greatest importance in elucidating and even quantitating the hemodynamics of these anomalies. However, these procedures are intricate in their application and require elaborate laboratory facilities for their use as well as a full-time, highly trained staff. More important, the technique of venous cardiac catheterization is not consistently applicable, at least in our hands, in the study of infants and very young children. We are aware of Cournand's experience in this regard and will be interested in his remarks on this point.

Serial contrast visualization of the cardiac chambers and great vessels (intravenous angiocardiography) was proposed in infants by Castellanos, Garcia, and Pereiras,[6] and in adults by Robb and Steinberg.[7] Sussman and associates,[8] in particular, have had a large experience with the procedure. Despite the enthusiasm of these workers, the technique has not, until very recently, had as wide an application as we feel it merits. The direct information as to the course of intracardiac blood flow and relative size and location of the cardiac

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chambers and great vessels which can be obtained by angiocardiography has been of the greatest value to us in establishing the exact diagnosis in borderline cases of congenital heart disease. It has been of particular value in differentiating the various types in which cyanosis is a prominent symptom. The method has the very great advantage of being applicable to patients of all ages; diagnostic serial radiograms are obtained as easily in small infants as in children and adults.

Successful angiocardiography requires two conditions. First of all, a sufficient volume concentration of dye (70 per cent Diodrast or 75 per cent Neo-iopax) must be moved rapidly into the zone to be visualized. This requires the very rapid intravenous injection of 40 to 50 c.c. of the dye in adults, and proportionately lesser amounts in children and infants. The needle size should be only slightly smaller than the vein used. Second, it is necessary to have equipment capable of producing a rapid sequence of radiographic exposures accurately synchronized with the presence of the dye in the heart and great vessels. Such newer automatized radiographic techniques as the tautograph,[9] developed by Wendell Scott in our Department of Radiology, make this possible. An improved model which we are now using is called the rapidograph[10] and utilizes a modification of the aerial camera of the Fairchild Camera and Instrument Company. With this camera, exposures are taken every two-thirds or one-half second, as desired.

When these two conditions are met, consistently good angiocardiograms are obtained by the intravenous method showing the heart and the pulmonary arteries. However, with dispersion of the dye through the pulmonary circuit and return to the left heart, there is frequently very poor delineation of the aorta and its major branches. For this reason it has been felt that injection of radiopaque material directly into the aorta would yield more clearly defined pictures of the aorta and its immediate branches. Dos Santos and associates,[11] and later Wagner,[12] had advocated direct puncture of the aorta through the paravertebral region. Fariñas,[13] on the other hand, had catheterized the femoral artery in Scarpa's triangle and passed a catheter to the desired level. Crafoord[14] and others have catheterized the brachial artery and successfully visualized the aorta by retrograde injection of dye. Finding the intra-arterial catheterization technique difficult, we decided to use the left carotid, and found after employing this method that Freeman[15] quite independently was utilizing a similar technique. After a moderately extensive trial, we are convinced that the retrograde arterial technique is a valuable method of diagnosis and evaluation in those cases where the lesion is of the aorta or its immediate branches. We are further convinced that introducing the dye into the carotid is simpler and superior to other techniques.

By this technique the common carotid artery, usually the left, is surgically exposed and provision made by loose ligatures to introduce a large cannula in a bloodless fashion. When the cannula is to be introduced, the distal tie is snugged down so that the dye cannot go into the cerebral circulation. The proximal tie is then brought down tight enough to shut off carotid blood flow

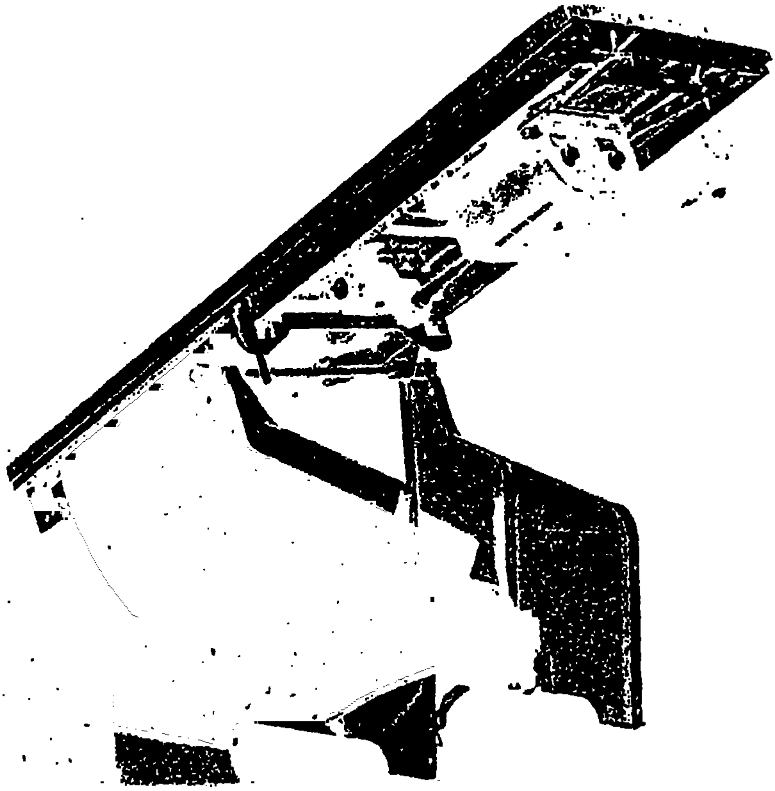


Fig. 1.—View of rapidograph table showing position of modified aerial camera. In this photograph, rapidographic table is tilted. Angiograms and aortograms are done with table flat.

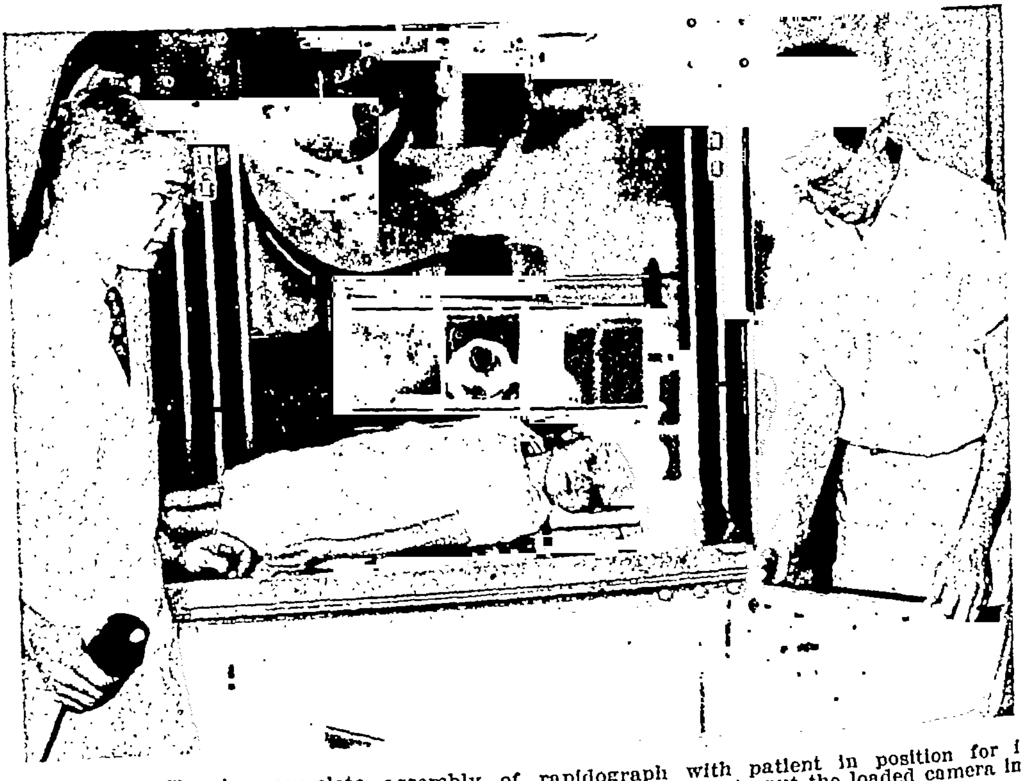
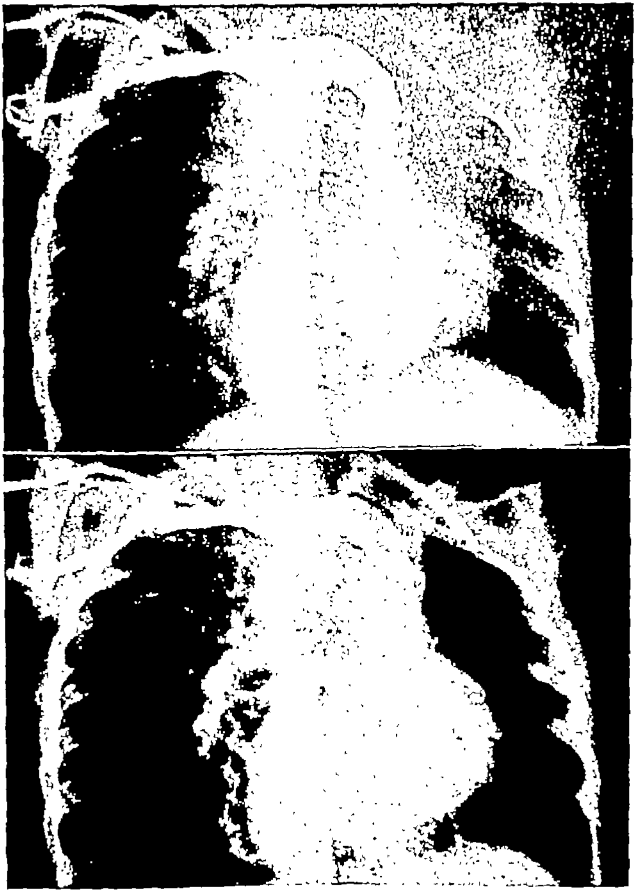


Fig. 2.—Showing complete assembly of rapidograph with patient in position for intravenous injection of Diodrast. Radiologist at right is preparing to put the loaded camera into position.

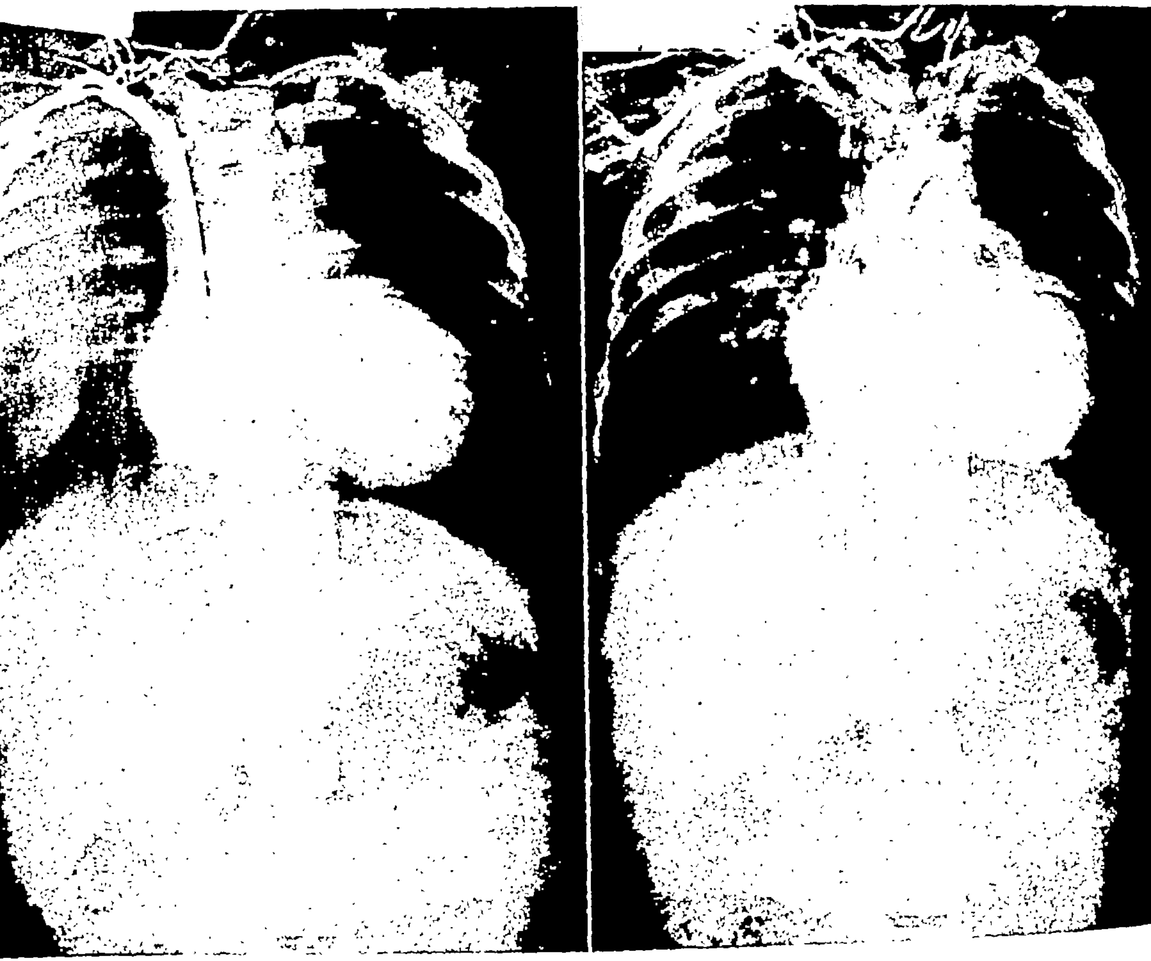
and the cannula introduced toward the heart through a small incision in the artery between the ties. When the cannula is introduced, a third ligature is tied over it to prevent leakage, and the proximal tie is released. The dye is then pushed in very rapidly by means of a large syringe. When the exposures have been completed, the proximal ligature is again tied and the needle removed. The opening in the artery is carefully repaired with 00000 Deknatel and the neck wound closed with silk.



Figs. 3 and 4.—Two films from the angiocardiographic series of a case of tetralogy of Fallot showing the typical findings. These reproductions are reversed so that the right side is to the left and vice versa. There is clearly demonstrated the filling of the left ventricle across a high septal defect with simultaneous filling of aorta and pulmonary artery. The pulmonary artery is significantly reduced in size.

By this method we have gained decisive information in cases of coarctation of the aorta, patent ductus arteriosus, aortic arch anomalies, and aneurysm.

In cases of coarctation, not only is the diagnosis made, which admittedly is not often too difficult, but the site and type are delineated. This latter information is of the greatest value in preoperative planning.



Figs. 5 and 6.—Angiocardiograms of a case of nonfunctioning right ventricle showing failure of the right ventricle to fill. The flow of the dye is from the superior vena cava to the right auricle, then to the left auricle and into the large left ventricle which gives rise to both the aorta and the pulmonary artery. Note how the latter structures fill simultaneously. The pulmonary arteries are smaller than normal. There is marked reflux into the hepatic veins.

In the infrequent but important borderline case of patent ductus arteriosus, retrograde visualization is decisive. The simultaneous opacification of sorta and pulmonary artery or the actual demonstration of the ductus are irrefutable evidence of ductal patency. Absence of these evidences of shunt can be confidently interpreted as excluding the existence of a patent ductus.

Aortic arch anomalies can be beautifully outlined even to the extent of showing the two limbs of an "aortic" ring.

Aneurysms can be visualized by actual filling or partial filling. In those that are filled with clot, there is enough suggestive evidence in the aortogram to make the diagnosis.

Since developing the tautograph and the rapidograph, we have done eighty-six visualizations. Of these, sixty-three were intravenous angiocardiograms and twenty-three were retrograde aortograms. So far as we have been able to discern from operations and post-mortems on this group, there has been but one wrong diagnosis.

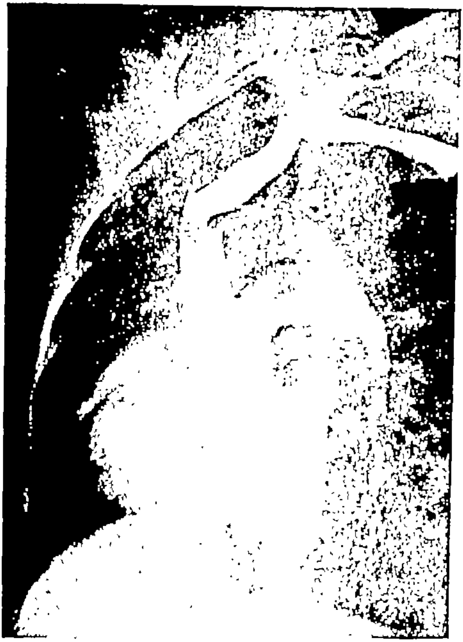


Fig. 7.—Film showing characteristic typical angiocardiographic features of an Eisenmenger's complex. Here again there is overriding with simultaneous filling of pulmonary artery and aorta and evidence of a high interventricular septal defect. The pulmonary artery is, however, larger than normal.

To date we have had no deaths or untoward event escribable to the dye or the method. Two deaths have occurred following angiocardiography, but in both instances the patients were very young infants and were extremely poor risks. Death was not unexpected. Needless to say, all patients are tested for possible sensitivity to the dye beforehand.

In the retrograde group there have been no complications attributable to the use of the carotid artery.

In conclusion, we would stress that angiocardiography is not to be recommended in every case of congenital cardiovascular heart disease. Despite our experience and the larger experience of others, it is not a method without some potential hazard. Moreover, as we said in the beginning, the diagnosis in most

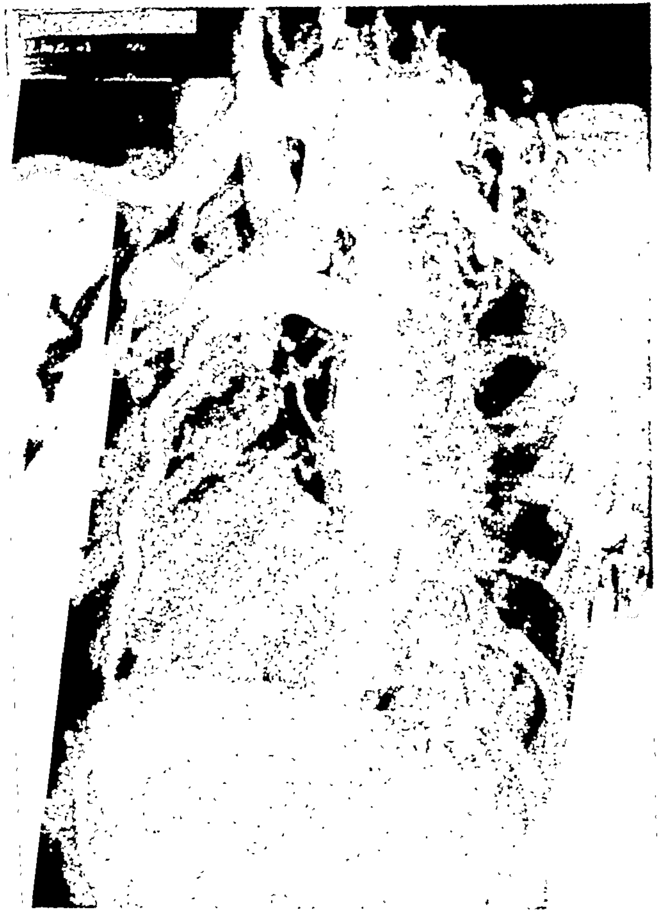


Fig. 8.

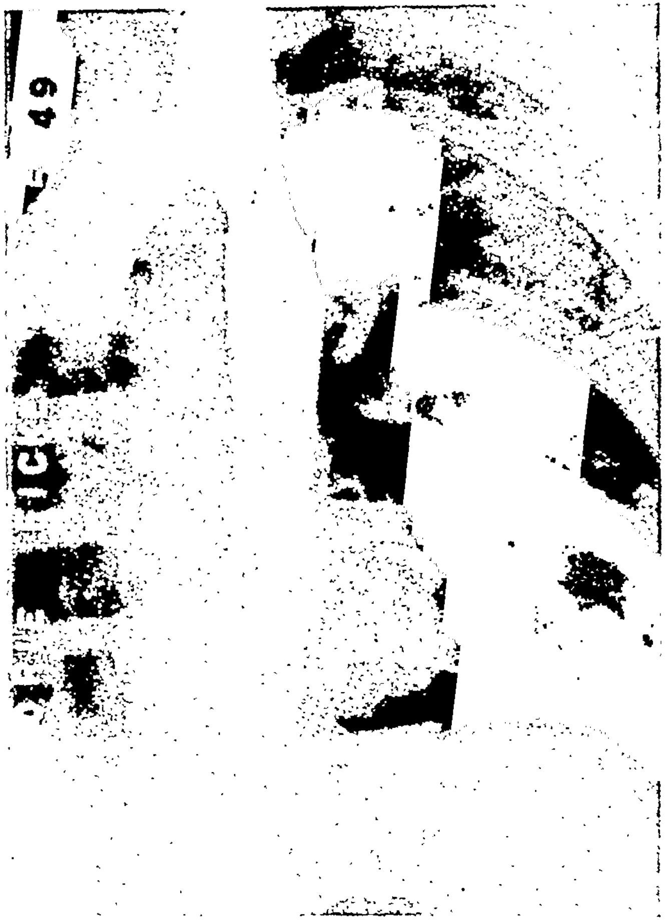


Fig. 9.

Fig. 8.—Aortogram done by the retrograde technique showing visualization of a typical case of coarctation of the aorta of the adult type. The lesion is accurately localized and valuable information is obtained concerning the length of the constricted segment. Note the enormous collateral channels.

Fig. 9.—Retrograde aortogram made one year after resection and anastomosis of aorta for coarctation of the aorta. Note the normal-sized lumen of the aorta and the regression of collateral channels.

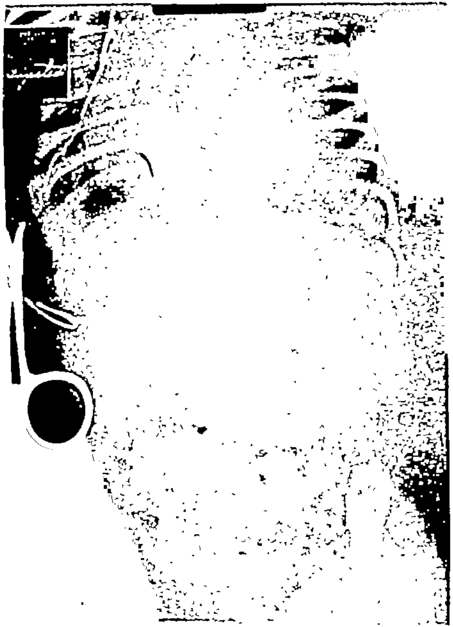


Fig. 10.

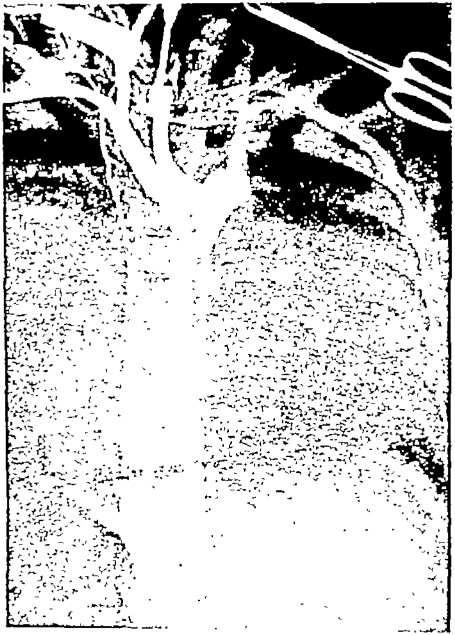


Fig. 11.

Fig. 10.—Retrograde aortogram of coarctation of the aorta of the infantile type. Note the long atretic segment.

Fig. 11.—Retrograde aortogram of aortic arch anomaly. Careful examination reveals the presence of aortic ring.

instances can be confidently arrived at by simple examination and fluoroscopy. Nor would we imply that visualization should supplant physiologic studies when these are indicated and obtainable.

In the all-important borderline group, however, we fieel that angiocardiography and retrograde aortography when properly done offer a reasonably simple, a very safe, and a very acurate method of diagnosis that is applicable to all age groups.

REFERENCES

1. Gross, R. E., and Hubbard, J. P.: J. A. M. A. 112: 729, 1939.
2. Blalock, A., and Taussig, H. B.: J. A. M. A. 128: 189, 1945.
3. Crafoord, C., and Nylin, G.: J. THORACIC SURG. 14: 347, 1945.
4. Cournand, A., and Ranges, H. A.: Proc. Soc. Exp. Biol. & Med. 46: 462, 1941.
5. Bing, R. J., Vandam, L. D., and Gray, F D., Jr.: Bull. Johns Hopkins Hosp. 80: 107, 1947.
6. Castellanos, A.: Cardiopatias Congenitas de la Infancia, La Habana, Cuba, 1948.
7. Robb, G. P., and Steinberg, I.: Am. J. Roentgenol. 41: 1, 1939.
8. Sussman, M. L., Steinberg, M. F., and Grishman, A.: Am. J. Roentgenol. 46: 745, 1941.
9. Scott, W. G., and Moore, S. A.: Am. J. Roentgenol. 62: 33, 1949.
10. Scott, W. G.: The Rapidograph, Presented Before the Thirty-Fourth Annual Meeting of the Radiological Society of North America, San Francisco, Calif., December, 1948.
11. Dos Santos, R., Lamas, A. C., and Caldas, J. P.: L'Arteriographie des membres et de l'aorte Abdominale, Paris, 1931, Masson & Cie.
12. Wagner, F. B.: Abdominal Aortography, New York Roentgen Society, November, 1946.
13. Fariñas, P. L.: Radiology 29: 29, 1937.
14. Crafoord, C.: Personal communication.
15. Freeman, N. E.: *Reported Before American College of Chest Physicians, Chicago,* 1948.

(See discussion on page 891.)

THE ROLE OF ANGIOCARDIOGRAPHY AND VENOGRAPHY IN MEDIASTINAL AND PARAMEDIASTINAL LESIONS

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SINCE the original publication of Robb and Steinberg[1] in 1938, relative to visualization of the chambers of the heart, the pulmonary circulation, and the great blood vessels in man, the procedure of angiocardiography has become of increasingly widespread use and application as a valuable diagnostic procedure. The fundamental interest in this presentation is to evaluate the results of our experience in using this procedure as a diagnostic aid in the differential diagnosis of tumors in the mediastinum and paramediastinal areas. Visualization of both innominate veins and the superior vena cava, by means of contrast media, has also been used as an aid in the differential diagnosis of these lesions as well as to determine the status of these veins in patients having primary carcinoma of the lung.

It is not our purpose to state any final conclusions in regard to the value of this procedure in the differential diagnosis, but rather to describe the results of our experience in a fairly large number of cases and to evaluate the lessons derived therefrom.

The use of angiocardiography in the differential diagnosis between tumors of nonvascular origin and vascular aneurysms has been a common practice in many clinics during the past few years. Attention was drawn to this method of approach by Sussman[2] in November, 1947. The value of this procedure in the differential diagnosis between aneurysm and other mediastinal tumors is quite apparent. This procedure also has demonstrated a considerable value in the differential diagnosis of intracardiac lesions and also in certain pericardial lesions.[3, 10] It is our opinion that the procedure may also be of considerable value in both nonvascular lesions of the mediastinum and certain paramediastinal diseases, in particular pulmonary malignancy.

In reviewing the results obtained in the series of patients which will be presented, we feel that there are five primary questions which need investigation. From the data obtained to date, a satisfactory answer to each of these questions is not yet obtainable. We feel that the problems, in order of their importance, appear to be as follows: (1) Angiocardiography as a method of differential diagnosis between vascular and avascular mediastinal and paramediastinal lesions. (2) How much diagnostic information can be obtained from this method in relation to nonvascular tumors in these areas? (3) What is the relative place of angiocardiography in the study of mediastinal and paramediastinal masses? (4) What are the special technical problems associated with

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venography and angiocardiography in the different types of mediastinal lesions encountered? (5) Of what value can angiocardiography be in the study of certain primary pulmonary lesions, in particular pulmonary neoplasms?

1. *The Role of Angiocardiography in the Differential Diagnosis Between Vascular and Nonvascular Mediastinal and Paramediastinal Lesions.*—The problem of the differentiation between intrinsic and transmitted pulsation of masses visualized on fluoroscopy is frequently encountered. The initial enthusiasm for the roentgenkymographic method of differentiation has proved a considerable disappointment. Certainly, angiocardiography has proved the best solution of this problem to date. Unfortunately, lesions of primary vascular origin are prone to contain large areas of blood clot which may forbid adequate definition by this method. However, the channels through this lesion will frequently show a sufficient distortion to be of diagnostic importance. Of equal value in the extravascular tumor can be the visualization of an area of extrinsic compression of a major vessel by the tumor in question. These findings are exemplified in the following patients.

CASE 1.—H. S., a 17-year-old college student, was found to have a superior mediastinal lesion in the right paratracheal area in the course of an x-ray screening project. Fluoroscopic examination showed evidence of pulsation in this mass, which was thought to be transmitted and appeared to be paradoxical in relationship to the pulsations of the ascending aorta. A marked change in the conformity of the mass is noted in comparing inspiration and expiration x-ray films of the chest. The lateral x-ray projection failed to give detailed definition of the posterior portions of this mass. A definitive diagnosis was only made upon obtaining satisfactory visualization of the innominate veins and superior vena cava by means of 70 per cent Diodrast as part of a complete angiocardiographic study. This revealed the presence of a large fusiform aneurysm of the right innominate vein and the superior vena cava. Irregularities on the surface of this lesion suggested the presence of daughter aneurysms. This diagnosis was confirmed at the time of operation, at which time the lesion was treated by the application of Polythene cellophane.

The angiocardiographic study was repeated six months following operation and showed definite evidence of decrease in the size of the lumen and thickening of the wall of the aneurysm. This patient has been reported in detail elsewhere.[4] (See Fig. 1.)

CASE 2.—K. L., a 24-year-old white man, had been treated on two previous occasions with deep x-ray therapy on the suppositional diagnosis of malignant lymphoma. On physical examination the patient demonstrated a very loud, to-and-fro, coarse murmur in the second interspace just to the left of the sternum. Fluoroscopic examination revealed the presence of a nodular mass in the region of the aortic knob and extending upward into the superior mediastinum, but there was no apparent evidence of pulsation.

Roentgenograms taken in the lateral projection showed what we felt to be a very characteristic diagnostic finding, namely, the presence of a shadow assuming the appearance of a small embryo. This pseudoembryo shadow seen in the lateral projection is felt, in this clinic, to be very strongly suggestive of a congenital aneurysm. The location of this shadow in the posterior mediastinal area suggested that the aneurysm arose from the aorta in contradistinction to the anterior position of such shadows presented by congenital aneurysms of the left pulmonay artery. This impression was confirmed upon detailed angiocardiographic examination, revealing the presence of a large multilocular aneurysm of the descending limb of the aortic arch. This finding was confirmed at operation. The lesion was also treated by the application of Polythene cellophane. (See Fig. 2.)

CASE 3.—T. L., a 32-year-old white man, presented a very similar history to patient K. L.; namely, he had undergone two courses of deep x-ray therapy on the presumptive diagnosis of mediastinal lymphoma. The lateral x-ray projection showed the presence of a large pseudoembryo shadow in the anterior mediastinal area, and angiocardiographic study confirmed the impression of a massive aneurysm of the pulmonary artery. This lesion was also confirmed at operation and treated by the application of Polythene cellophane. (See Fig. 3.)

CASE 4.—A. L., a 54-year-old white coal miner, had suffered from severe precordial and bilateral arm pain for sixteen months. The presumptive diagnosis had been recurrent

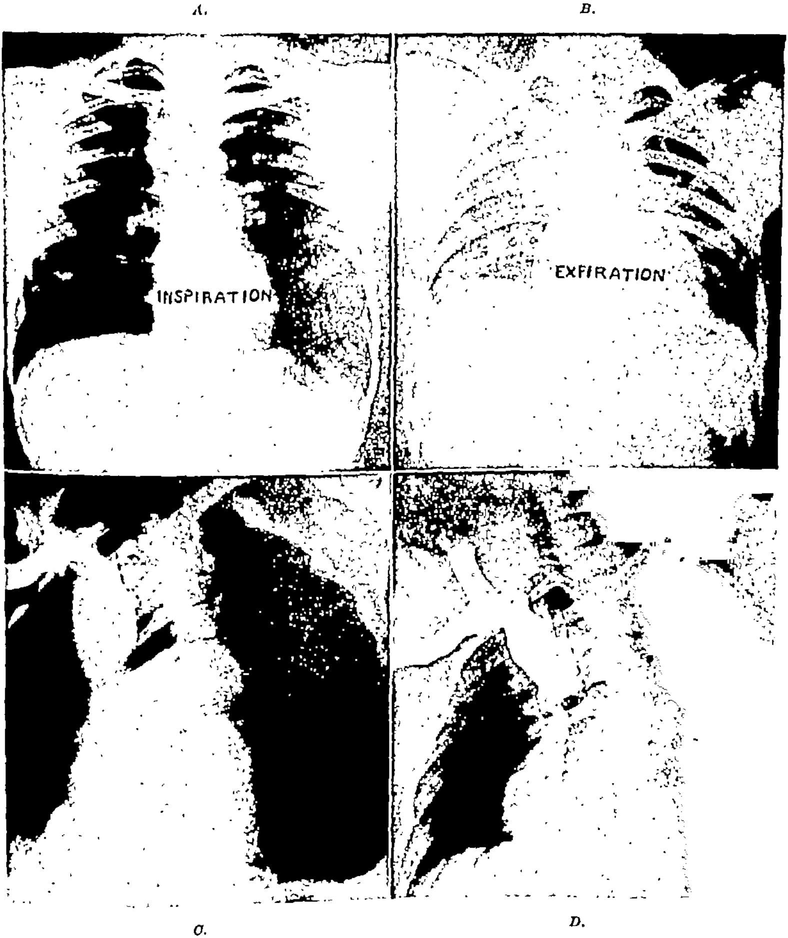


Fig. 1, *A* to *D* (Mr. H. S.).—Right paratracheal mass. Angiocardiogram showed this to be an aneurysm of the vena cava. *D* shows angiocardiogram six months after operation.

coronary occlusion and angina pectoris. He had undergone recent study at another clinic, which revealed the presence of a mass with apparent pulsations in the region of the ascending aorta. He was referred to this clinic with a tentative diagnosis of aneurysm of that structure.

Fluoroscopic examination certainly suggested intrinsic pulsation. There were no abnormalities on examination of repeated electrocardiographic studies. The extravascular character of the lesion could be defined only by means of the use of the angiocardiogram, which revealed no abnormality in the superior vena cava, cardiac chambers, or ascending aorta. There was no apparent compression of the ascending aorta by this lesion.

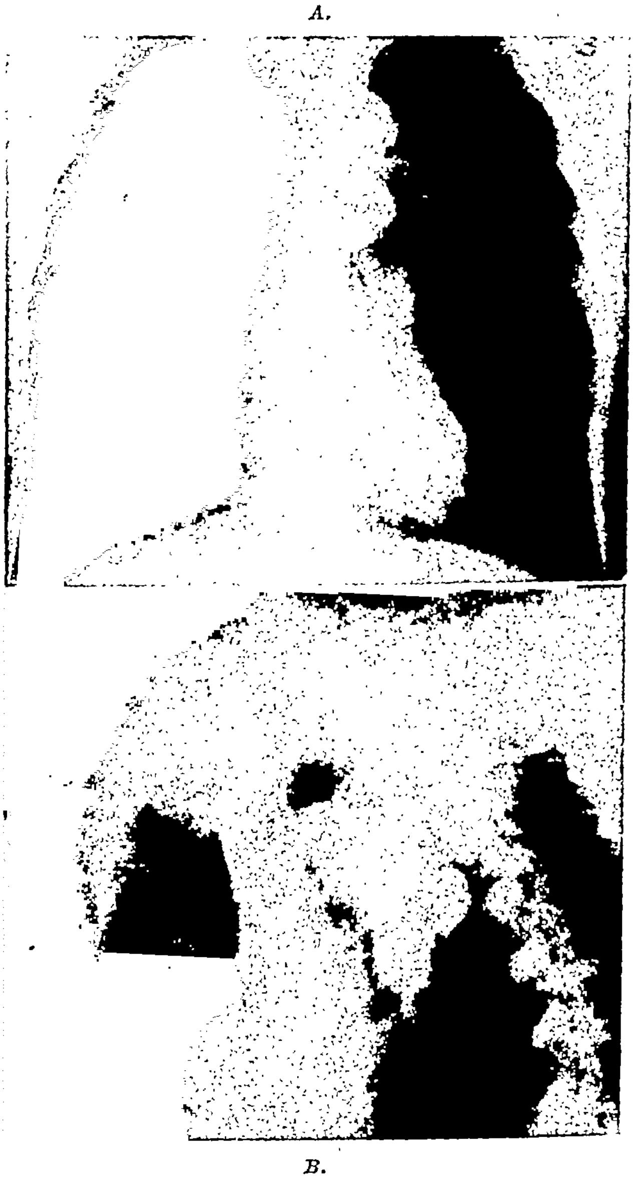


Fig. 2, *A* and *B* (Mr. K. L.).—Showing large multilocular aneurysm of aorta.

Exploratory thoracotomy revealed that the primary shadow had been produced by an adenocarcinoma of the right lower pole of the thymus gland. The presence of metastatic lymph nodes invading the wall of the ascending aorta was considered to be the explanation for the patient's persistent pain. This pain was relieved by an extensive upper dorsal sympathectomy. (See Fig. 4.)

Case 5.—I. A. R., a 48-year-old white man, had a cough of two weeks' duration, and x-ray examination revealed the presence of a very large mass occupying the left superior paramediastinal region.

Physical examination revealed definite bulging of the second and third left anterior interspaces with visible and palpable pulsations. The clinical impression at that time was massive aneurysm of the aorta. Fluoroscopic examination strongly suggested the presence of intrinsic pulsation of the mass. A lateral x-ray projection showed the presence of an apparent cleft in the inferior aspect of the mass and an area of posterior nodular projection thought to suggest daughter aneurysm. Angiocardiographic studies revealed a very definite distortion of the vascular pattern in the apical portion of the left upper lobe; when the

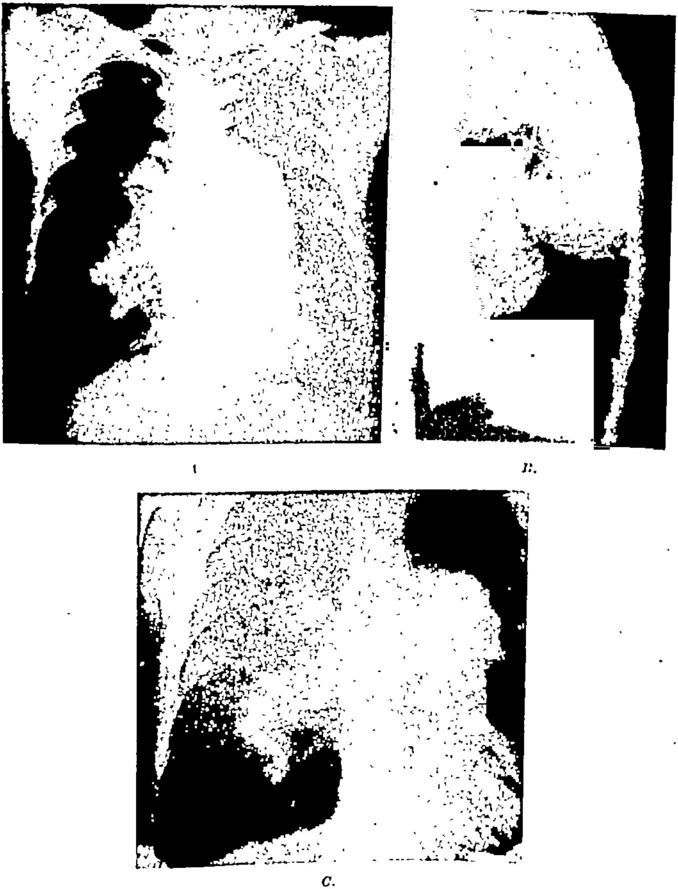
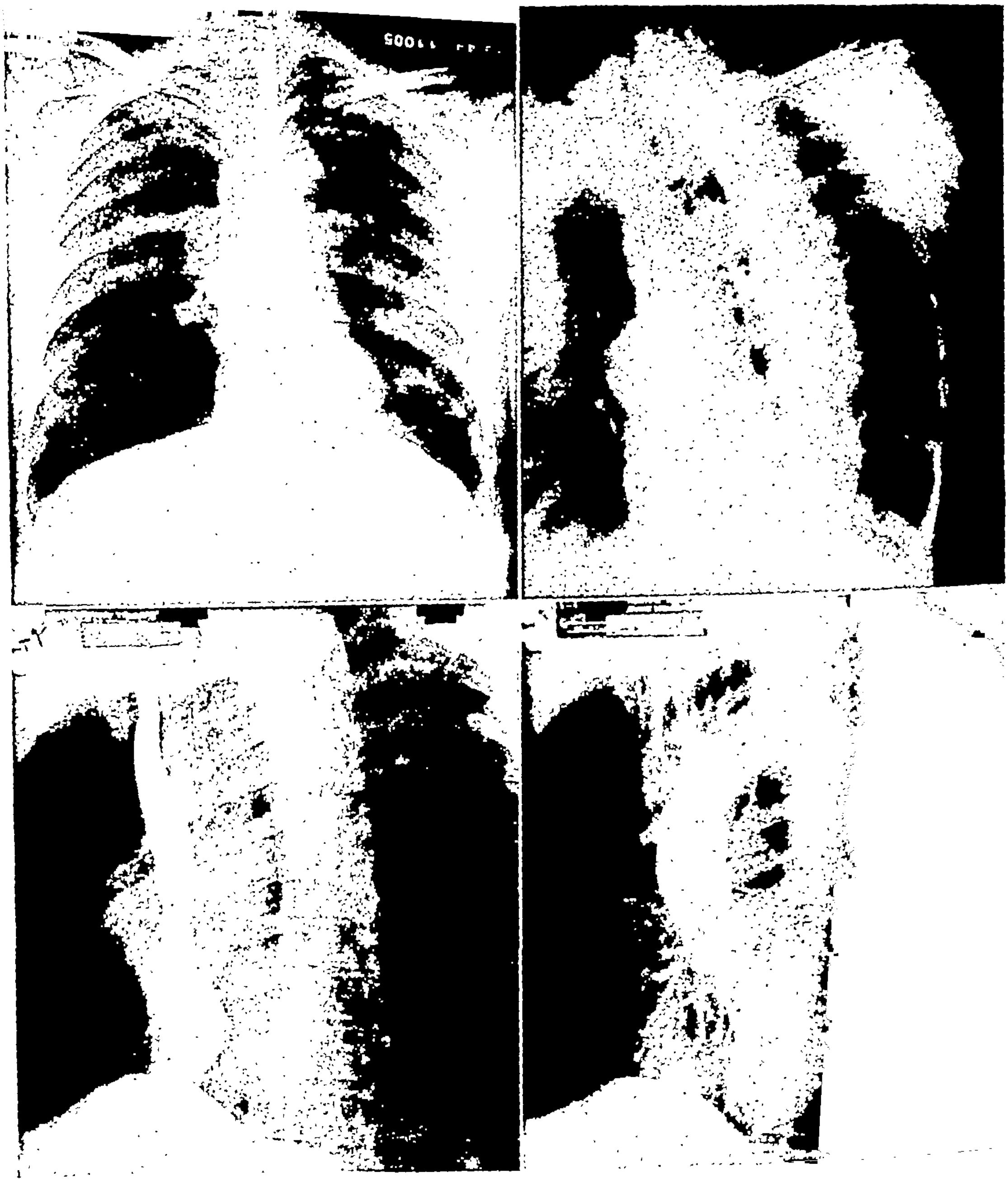


Fig. 3, *A* to *C* (Mr. T. L.).—Large aneurysm of the pulmonary artery. Note, on lateral x-ray, pseudoembryo formation. Angiocardiogram confirms diagnosis.

aorta was visualized, there was no evidence of aneurysm, but rather, a definite area of extrinsic compression was demonstrated. The working diagnosis, therefore, was changed from aortic aneurysm to primary pulmonary carcinoma. The patient was treated by left total pneumonectomy which revealed a squamous carcinoma of the left upper lobe. (See Fig. 5.)

CASE 6.—G. T., a 56-year-old white man, had a history of an episode of extremely severe pain extending from the left anterior part of the chest through to the back, nine



A. B. C. D.

Fig. 4, *A* to *D* (Mr. A. L.).—Malignant thymoma. Angiocardiogram showing lesion to be entirely extravascular.

weeks prior to consultation. No unusual physical findings were present, and x-ray examination revealed the presence of a large mass occupying almost the entire extent of the posterior mediastinum. This lesion was suspected of being a dissecting aneurysm, and confirmation

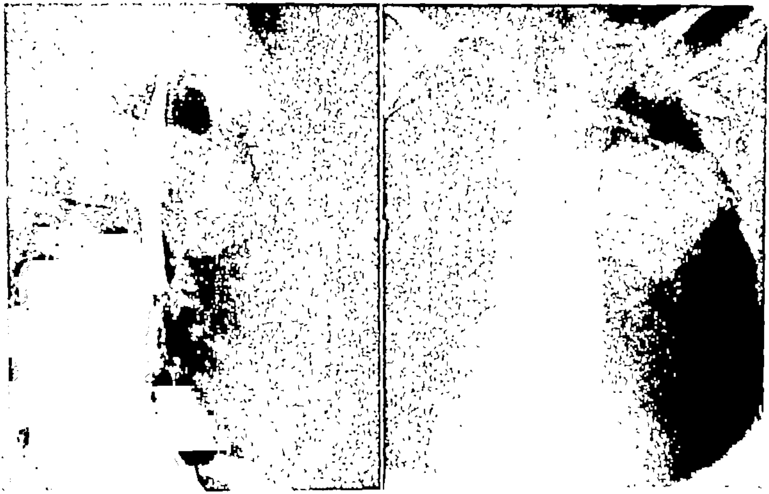


Fig. 5. *A* and *B* (Mr. I. A. R.).—Angiocardiogram A shows evidence of lateral compression of aortic knob. Diagnosis was carcinoma of the left upper lobe.

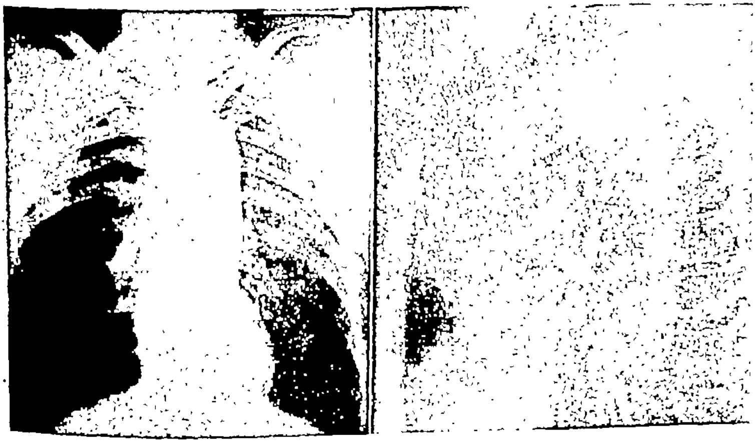


Fig. 6. *A* and *B* (Mr. G. T.).—Angiocardiogram shows double channel effect on lateral view. This patient had dissecting aneurysm of aorta.

was obtained by angiocardiographic studies. This patient has been presented in detail elsewhere to emphasize the presence of a double channel on angiocardiographic studies of these lesions.[5] (See Fig. 6.)

CASE 7.—E. W., a 56-year-old white man, was seen with the presenting complaints of cough, fatigue, and vague discomfort of the upper part of the chest. X-ray and fluoroscopic studies revealed the presence of a rather poorly defined mass in the right paramediastinal area. The venous pressure studies were within normal limits. The differential diagnoses suggested involved partial atelectasis of the right upper lobe secondary to bronchiogenic carcinoma, mediastinal lymphoma, or tumor of vascular origin. Visualization of the right innominate vein, and superior vena cava by means of 70 per cent Diodrast readily demonstrated that the mass was medial to these structures, and there was no visible abnormality of these veins. The irregular contour of the lesion, plus its position medial to the major venous structures, led to a presumptive diagnosis of lymphosarcoma which was subsequently proved true.

It is felt that the value of this procedure in the differential diagnosis of lesions of this type needs no further discussion and is readily acceptable. (See Fig. 7.)

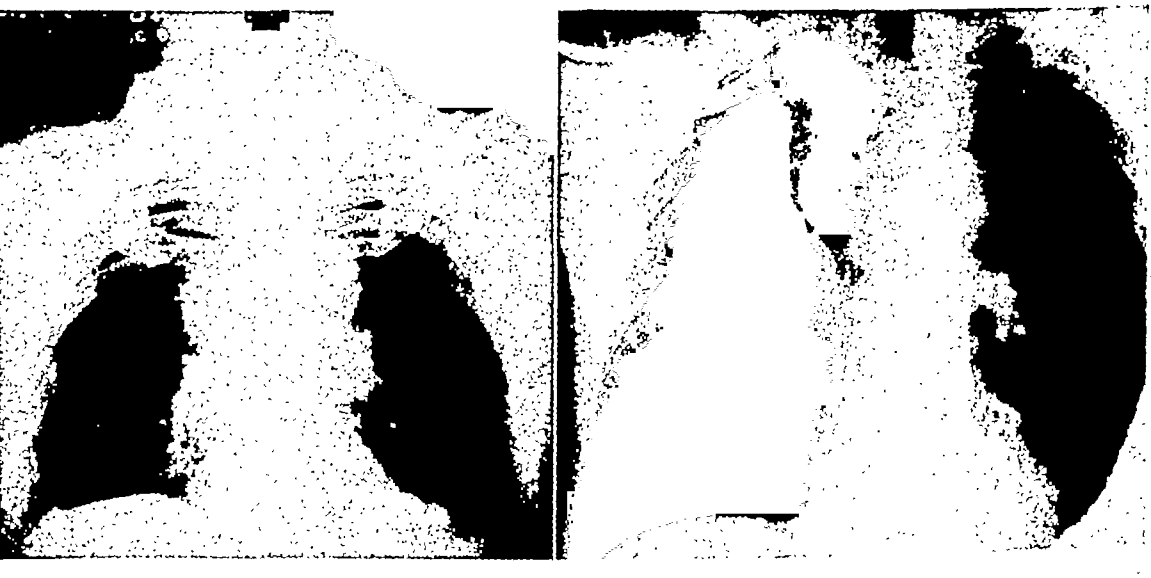
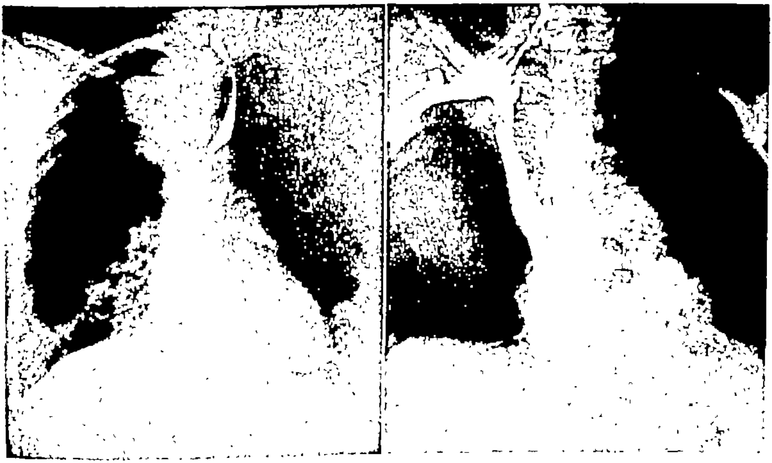

A. B.

Fig. 7, *A* and *B* (Mr. E. W.).—Showing marked lateral deviation of right innominate vein and vena cava. Diagnosis was mediastinal lymphosarcoma.

2. *How Can Valuable Diagnostic Information Be Obtained From Angiocardiography in Nonvascular Mediastinal and Paramediastinal Tumors?*—This is probably the most difficult question to be answered and the one to which the least satisfactory conclusions can be made at this time. It is felt that venography and angiocardiography can help in the localization of the borders of nonvascular mediastinal tumors. It is possible that on some occasions it may suggest the point of origin of the pedicle of these lesions. The frequency with which such information can be obtained can be determined only after obtaining considerably more information than is at present at hand. The basic information consists in obtaining evidence of vascular distortion of a specific pattern in relation

to certain primary lesions and, second, in the definition of vascular distortion due to invasive processes into the vascular structures either by the primary lesion or by metastatic neoplasm particularly in mediastinal lymph nodes. It is felt that there is a specific place for visualization of the superior vena cava when there are malignant lesions in the pulmonary system. The displacement of certain vascular structures is also felt to be suggestive help in determining the point of origin of a mass. Such information can also be of considerable value to the operating surgeon.

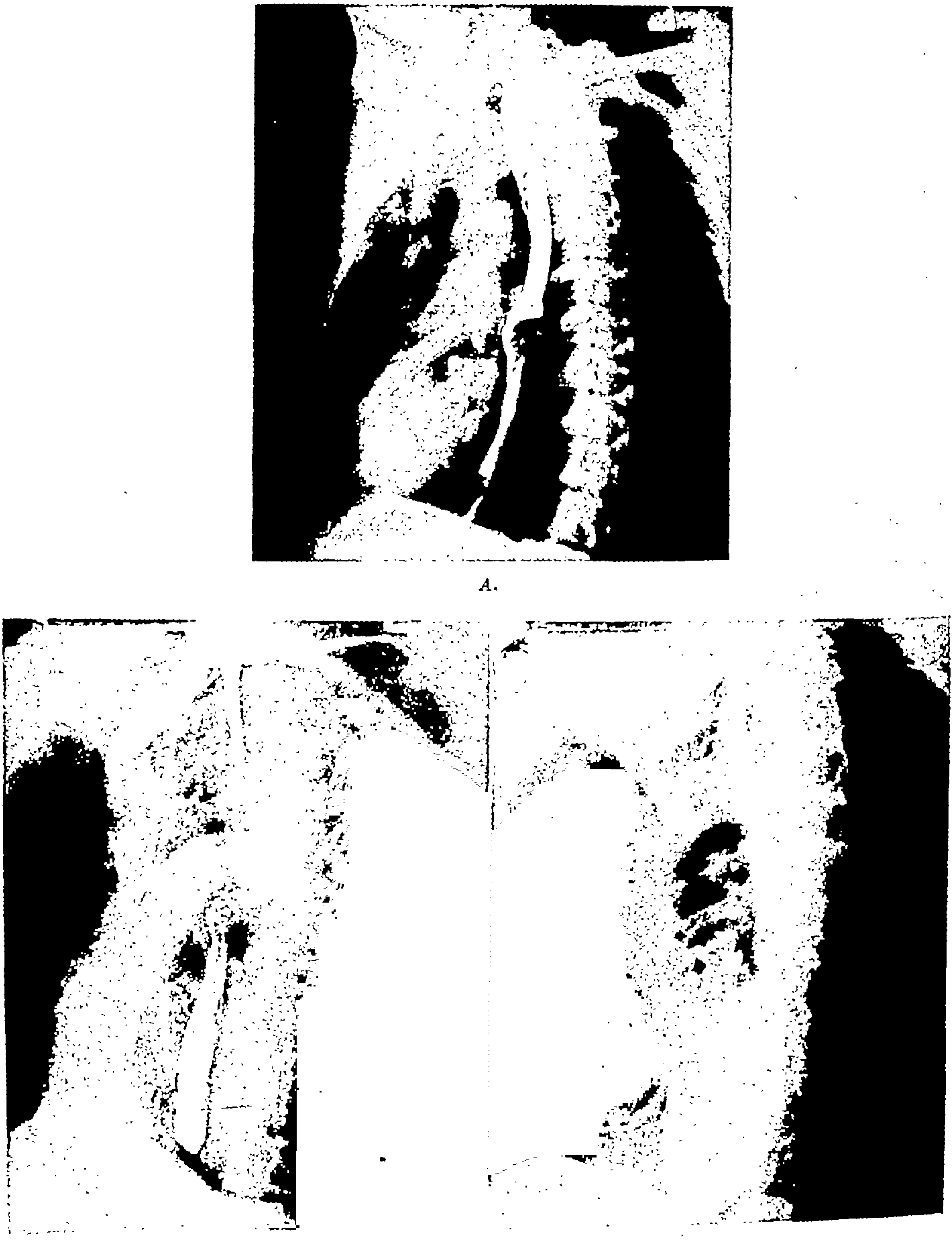
CASE 1.—R. W., reported upon in the foregoing section, was felt to be an illustration of the distortion of the right innominate vein and superior vena cava by involvements of the lymph nodes in the right paratracheal region by a malignant lymphoma. The lateral displacement of these structures limits the probable tissue of origin of this tumor to those structures which are normally contained between these vessels and the right tracheal wall. (See Fig. 7.)



A. *B.*

Fig. 8, *A* and *B* (Mrs. R. T.).—Showing evidence of a lateral displacement of right innominate vein. Contrast dye injected through left side would probably have been of considerable help in localizing this lesion, as would a lateral venogram taken with dye in right innominate to outline compression of cava.

CASE 2.—R. T., a 49-year-old white woman, was admitted to the hospital with symptoms of tracheal obstruction. The patient was quite obese, and satisfactory palpation of the thyroid area could not be obtained, but it was felt that the thyroid gland was probably not abnormal. X-ray studies revealed the presence of a large rounded mass with a smooth contour occupying the superior mediastinum and deviating the trachea to the left. Angiocardiographic studies were carried out despite the presumptive diagnosis of substernal thyroid adenoma in order to evaluate this procedure in association with this lesion. The study did show a definite lateral deviation of the innominate vein on the right by the mass, but essentially no visible distortion of the superior vena cava on films taken in the anteroposterior projection. Although the innominate vein was displaced laterally, there was no irregularity in its wall, and its smooth contour further suggested the possibility of a benign lesion. (See Fig. 8.)



A.

B.

C.

Fig. 9, *A* to *C* (Mr. S. A. K.).—Note that the tumor compressing the esophagus is not related to any vascular lesion. Note the effect of associated filling of the esophagus with contrast media during angiocardiography.

CASE 3.—S. A. K., a 25-year-old white man, was admitted to the hospital because of symptoms associated with a duodenal ulcer. During the course of barium studies of the gastrointestinal tract, a major area of compression of the mid-portion of the esophagus was revealed. Following this discovery the patient related that he had had some dysphagia for several months. This area of compression was in the region of the major pulmonary vessels. Esophagoscopic examination revealed only evidence of extrinsic obstruction. Angiocardiographic study was carried out with the presence of barium in the esophagus. This study revealed no abnormality of the vascular bed, in particular, no enlargement of the left pulmonary artery. The diagnosis of nonvascular tumor of the esophageal wall was made, presumptively a leiomyoma. This was confirmed at operation. (See Fig. 9.)

CASE 4.—A. O. L., a 61-year-old white man, was seen with the complaints of fatigue, cough, and a vague discomfort of the upper part of the chest. X-ray examination revealed the presence of a right superior paramediastinal mass. Bronchoscopic examinations were noncontributory. Special studies did not reveal evidence of increased venous pressure. Diodrast visualization of the superior vena cava demonstrated a very definite obstruction of this vessel with the density of the paramediastinal mass present both medial and lateral to the superior vena cava. The presumptive diagnosis of bronchiogenic carcinoma with mediastinal metastasis was made and confirmed at a later date upon the discovery of an involved right axillary lymph node. (See Fig. 10.)

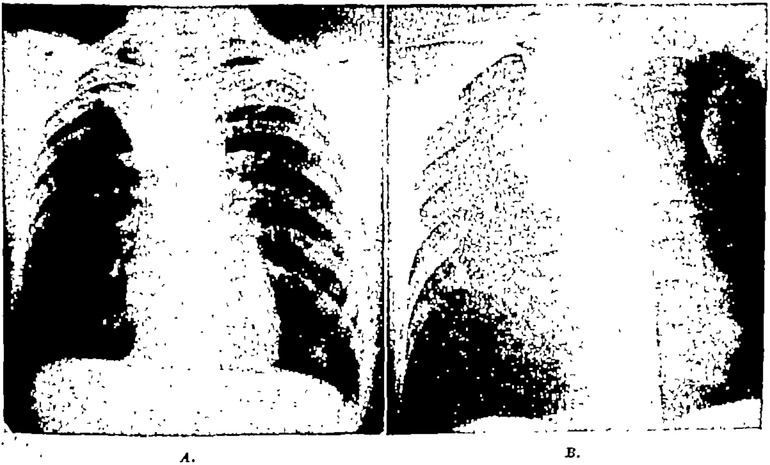

A. B.

Fig. 10, *A* and *B* (Mr. A. O. L.).—Right paramediastinal mass In *B* is seen venogram showing obstruction and lateral displacement of right innominate vein.

3. *What Is the Relative Place of Angiocardiography in the Study of Mediastinal and Paramediastinal Lesions?*—Certainly a satisfactory answer to this question will not be obtained without considerable further use of this method of diagnosis. It is felt that certain basic concepts can be presented. There is frequently considerable difficulty in defining the site of origin of masses in the right superior paramediastinal region. The normal position of the right innominate and superior vena cava structures make venographic studies of considerable value in this area. It is felt to be a more uniformly applicable and less

dangerous method of differential diagnosis than the institution of an artificial pneumothorax. Unfortunately, the constant anterior position of the left innominate vein does not usually allow this procedure to be of value in left superior paramediastinal masses. There may be confusion between aneurysms of the innominate, the left common carotid, or left subclavian arteries, with tumors of lymphatic origin or thyroid. It has been our experience on several occasions to change the presumptive diagnosis of lymphoma in the presence of a right paratracheal mass to that of syphilitic aneurysm of the innominate artery. A similar experience has occurred in the presence of a syphilitic aneurysm of the left common carotid artery when the presumptive diagnosis was substernal thyroid adenoma. There is little question of the value of angiocardiography of lesions of the middle mediastinum, which, by definition, is that area of the mediastinum consisting of the pericardium and its contents. A valuable supplementary method of diagnosis in lesions of this area consists in the use of cardiac catheterization. In lesions of the anterior and posterior mediastinum, angiography may be of relatively little value unless it is required for the differential diagnosis between intrinsic and transmitted pulsation. In the study of masses of the lower portions of the anterior and posterior mediastinum, the use of pneumoperitoneum and pneumothorax is usually adequate for diagnosis and should be utilized before the use of angiocardiography.

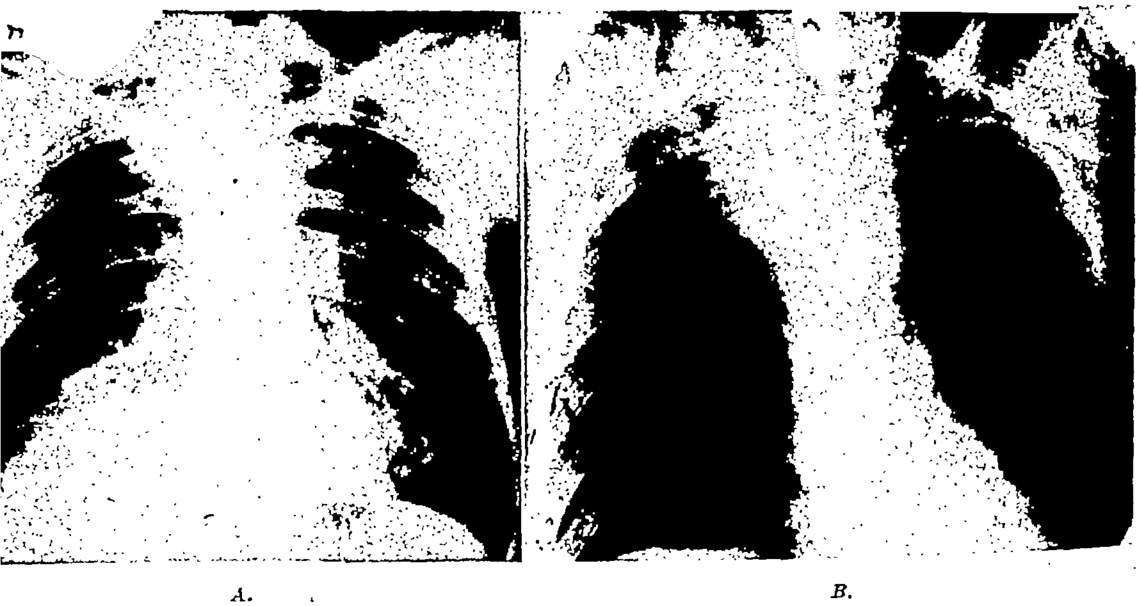

A. B.

Fig. 11, *A* and *B* (Mr. W. B.).—Right paratracheal mass with associated atelectasis of right lower lobe. Angiocardiogram shows this to be a large aneurysm of the innominate artery.

Unfortunately we cannot present any evidence of the value of visualization of the inferior vena cava which has been described by other authors.[6, 7, 8] In retrospect there are at least three instances in our experience in which this method could have been of considerable value. In one patient with a chondrosarcoma of the chest wall, presenting x-ray evidence of projection toward the area of the inferior vena cava, exploratory operation revealed definite evidence of invasion of this structure, with marked displacement. A second instance of unusual aneurysm of the heart wall with marked displacement of this structure could also have been considered. A third potential instance of an incarcerated hernia of the foramen of Morgagni, with compression of this vessel, might also have yielded diagnostic information upon the use of angiocardiogram.

The subject of the various methods of diagnosis of mediastinal tumors is contained in other publications by one of us (O.A.A.).[9] Cases felt to demonstrate points brought out in this discussion are illustrated by the following reports.

CASE 1.—W. B., a colored man 47 years of age, was admitted because of fever, pain in the right lower part of the chest, and cough. The patient had clinical findings of pneumonic consolidation of the right lower lobe, but x-ray study also showed the presence of a large right superior paramediastinal mass. There was also evidence of some partial obstruction in the right upper and middle lobes. Fluoroscopic examination failed to reveal any evidence of intrinsic or transmitted pulsation in the right paramediastinal shadow. Further x-ray examinations were felt to be suggestive that this lesion was a lymphoma. The presence of a positive Wassermann test and a degree of partial obstruction to the right upper lobe were felt by others to be suggestive that the lesion was aneurysmal in character. The presence of a syphilitic aneurysm of the innominate artery was proved by the use of angiocardiography. This was confirmed at operation when the lesion was treated with the application of Polythene cellophane. (See Fig. 11.)

CASE 2.—G. D., a 33-year-old colored woman, was admitted to the hospital because of intractable cough. X-ray examination revealed the presence of a superior mediastinal mass, rather centrally placed, with some deviation of the trachea to the right. The basal metabolic rate was plus 60, and there were several clinical findings suggestive of thyrotoxicosis. The type of distortion of the trachea, the presence of partial obstruction throughout the pulmonary tree, and the presence of a positive Wassermann test seemed to suggest the possibility of aneurysmal disease. This could be confirmed only by the use of angiocardiogram, which demonstrated the presence of a syphilitic aneurysm of the left common carotid artery. This patient was treated by bilateral decompression procedures, and subsequent Polythene cellophane application to the aneurysm. Following decompression procedures, the suggestive evidence of thyrotoxicosis disappeared. (See Fig. 12.)

CASE 3.—Mrs. R. S. W. was admitted with the primary complaint of marked exertional dyspnea. The patient had a slight prominence with suggestive pulsation in the third left anterior interspace. She showed severe evidence of dyspnea and cyanosis on very mild effort despite the presence of a vital capacity of 4.2 liters. Fluoroscopic examination revealed the presence of a large mass in the left paramediastinal area, with apparent intrinsic pulsations. Angiocardiographic studies proved the presence of a massive aneurysm of the main pulmonary artery. This lesion showed rapid progressive enlargement and was treated by the application of Polythene cellophane. Ventricular fibrillation occurred during the postoperative period, which was fatal, and autopsy examination revealed an extremely diffuse arteriolosclerosis of the entire pulmonary arterial bed. This patient has been reported in detail elsewhere. (See Fig. 13.)

CASE 4.—Mrs. J. A., a 67-year-old white woman, was discovered to have a large mass in the right cardiophrenic angle. The diagnosis of this lesion was very readily proved by the institution of a pneumoperitoneum, revealing the filling of a large hernial sac surrounding an omental hernia entering the thorax through the foramen of Morgagni. (See Fig. 14.)

4. *What Are the Special Technical Problems Associated With Venography and Angiocardiography in the Different Types of Mediastinal Lesions Encountered?*—The complete answer to this question is not considered applicable in a paper of this type and would more appropriately occur in one of the jour-

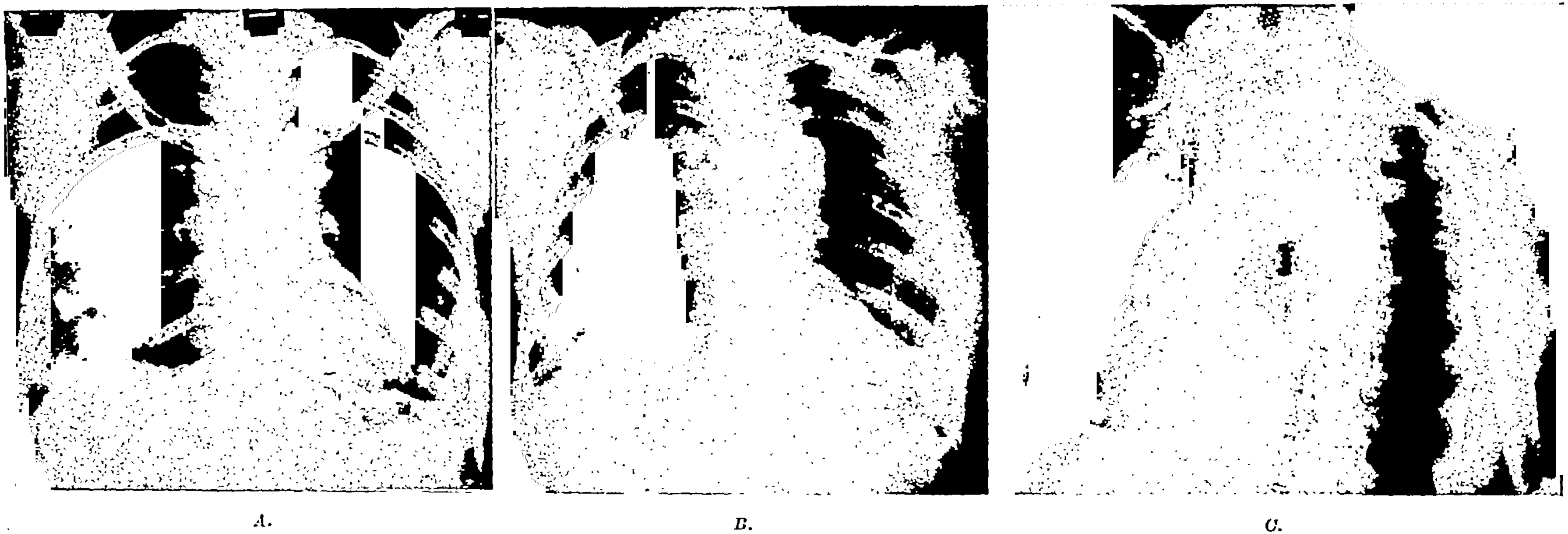


Fig. 12 (Mrs. G. D.).—Superior mediastinal mass. *A*, *B*, Posteroanterior views show before and after decompression of the chest. *C*, Angiocardiogram shows filling of the mass from the aorta.

nals of roentgenology. We do feel that it is important to mention that it is frequently necessary to obtain angiocardiographic studies in different positions. In some cases it would appear to be of value to obtain a venogram in the lateral position and a subsequent angiocardiogram in the anteroposterior or one of the oblique positions. It seems to be particularly valuable in lesions which are known to distort the esophagus, to obtain the angiocardiogram with contrast media also present in the esophagus. In certain instances the dilution factor

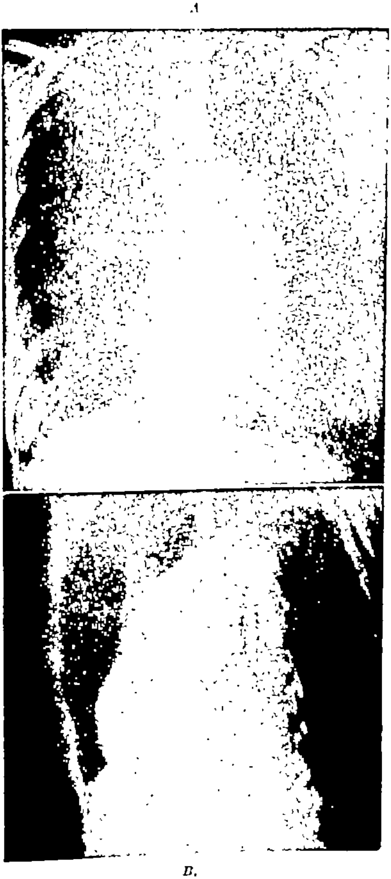


Fig. 13 (Miss R. S. W.).—*A*, Posteroanterior view shows mass, middle mediastinum. *B*, Angiocardiogram shows massive aneurysm of the left pulmonary artery.

may be sufficient that a satisfactory visualization of the aorta and its major branches cannot be obtained by the classical method of injection of the Diodrast media into a vein. In such conditions it would be advisable to carry out one of the various methods of direct arterial injection of the contrast media. This can

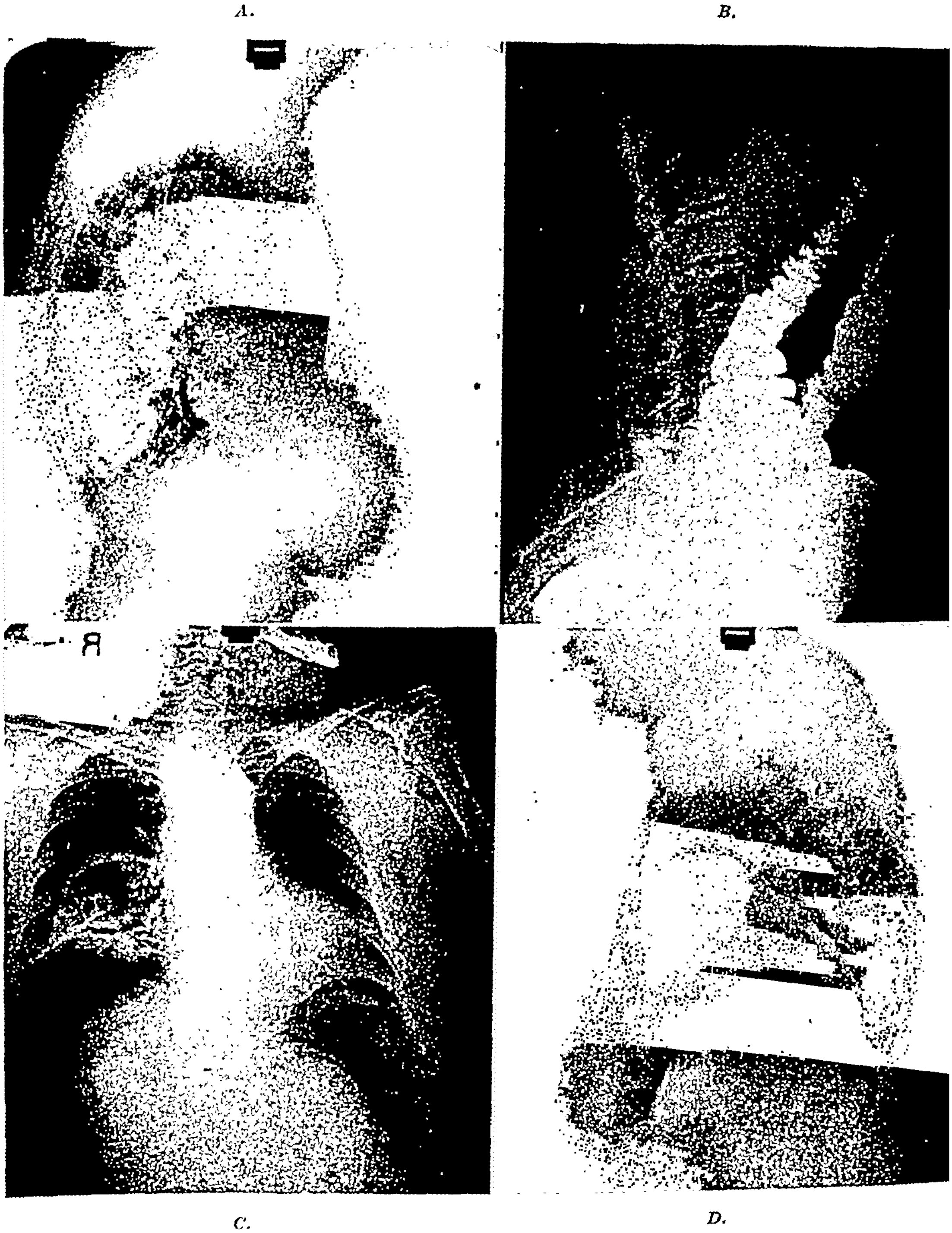


Fig. 14, *A* to *D* (Mrs. J. A.).—Foramen of Morgagni hernia showing two diagnostic features: *B*, barium study of colon shows inverted "V" formation. Pneumoperitoneum showing filling of hernia sac above diaphragm.

be done by catheterization of the radial artery, or by direct injection into one of the carotid arteries for retrograde injection. It is felt to be of utmost importance that a very careful fluoroscopic examination and review of the various directional x-ray examinations should be carried out first in order to determine the proper position for angiocardiography. In some instances angiocardiography may be repeated at the same sitting in different positions.

It is also felt that lesions appearing in the superior mediastinum on the left should first be examined by injection of the contrast medium into the antecubital vein of the left arm. In comparable fashion, right superior mediastinal lesions would require use of the right antecubital vein. In some instances this will reveal a complete obstruction of this structure and satisfactory angiocardiography can be carried out only by use of the contralateral arm. It is also suggested that in some instances it could be of value to do concomitant bilateral injection of the contrast substance. Exemplary patients are presented as follows.

CASE 1.—Mrs. R. T., who has been described previously as showing deviation of the right innominate vein in relation to a substernal thyroid adenoma, should also have been studied in the lateral projection to determine the effect upon the superior vena cava. This would have required injection of the contrast media into the opposite arm from that which was used. (Fig. 8.)

CASE 2.—J. P., a 51-year-old white man, was admitted with symptoms of circulatory disturbances in the right arm in association with symptoms of tracheal compression. The initial attempts at angiocardiography were unsuccessful due to the complete obstruction of the vein. It was necessary to inject the left antecubital vein in order to obtain a satisfactory angiocardiogram. There was just sufficient contrast medium present to allow the diagnosis of aneurysm of the innominate artery, and a more satisfactory visualization could have been obtained by retrograde arterial angiocardiography. (See Fig. 15.)

CASE 3.—J. H., a 46-year-old colored man, was admitted with the main complaint of esophageal obstruction, weight loss, and thoracic pain. X-ray studies revealed the presence of a large mass displacing the esophagus posteriorly in its mid-portion. The lesion did not appear to pulsate on fluoroscopic examination, and appeared to be of uniform density on the study of the lateral x-ray projection. Angiocardiographic study was carried out with concomitant visualization of the esophagus with barium. The angiocardiogram seemed to show that the lesion was not of vascular origin. Unfortunately the patient suffered a rapid downhill course, and post-mortem examination was not permitted.

5. *Of What Value Can Angiocardiography Be in the Study of Certain Primary Pulmonary Lesions, in Particular, Pulmonary Neoplasm?*—This topic has been mentioned in some detail elsewhere, with mention that a rather large percentage of patients having primary carcinoma of the lung show a definite disturbance of the vascular pattern of the pulmonary tree.[11] It is also known that a certain percentage of patients will not show abnormality of the vascular bed in the presence of pulmonary malignancy, and it will involve, therefore, a very considerable number of cases to determine the exact value of this procedure in relation to carcinoma of the lung.

In recent months we have tried to institute this procedure as a routine part of the diagnostic work-up of probable pulmonary malignancy patients. It has been used in fourteen instances, and in twelve patients definite evidence of vascular abnormality could be demonstrated. In four instances a demonstrable distortion of the pattern of the superior vena cava was present. In seven patients unquestioned abnormality of the pulmonary arterial system could be demonstrated. These all showed varying degrees of obstruction of the nutrient artery to the involved area of the lung. It was of most demonstrative value in lesions

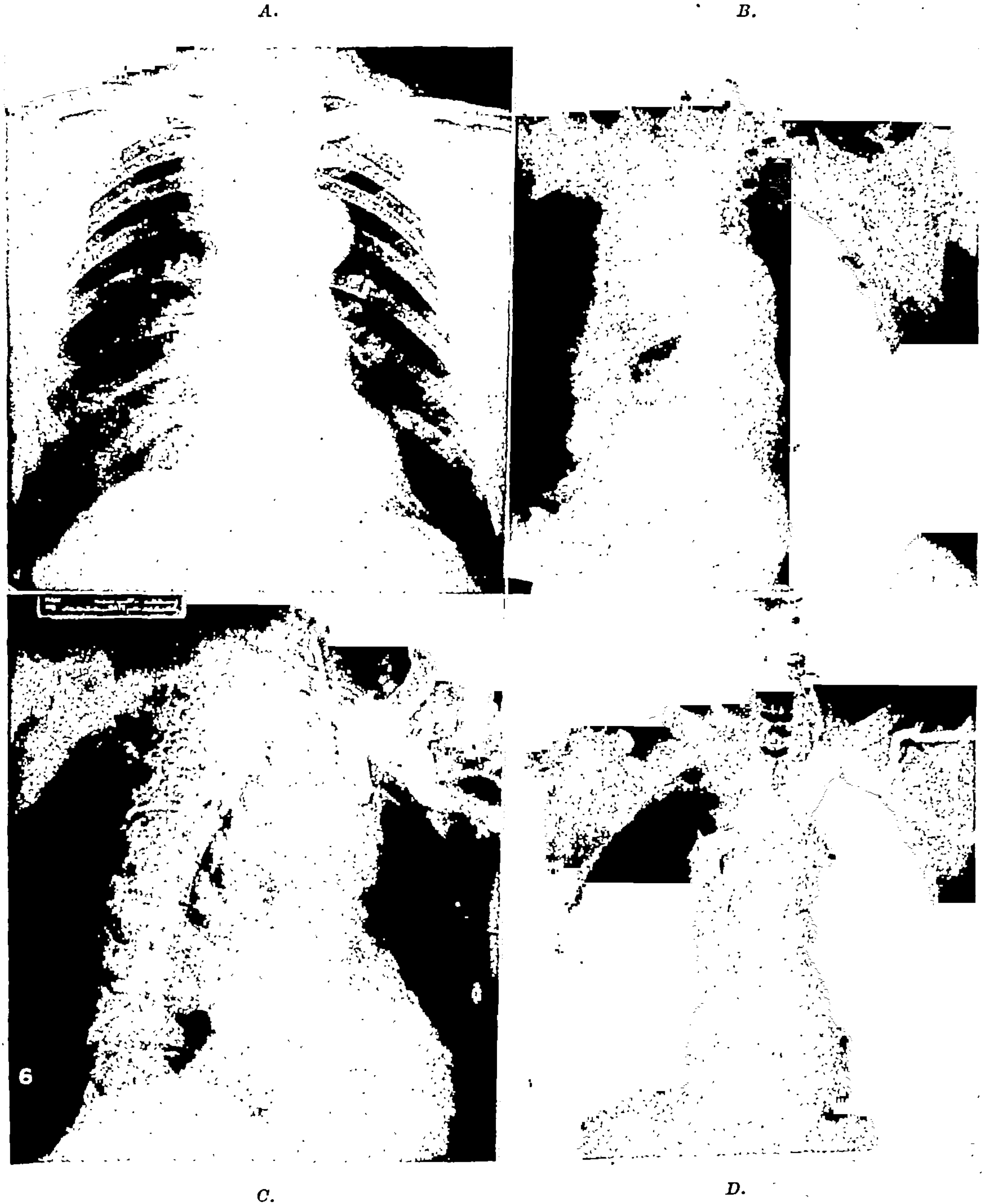
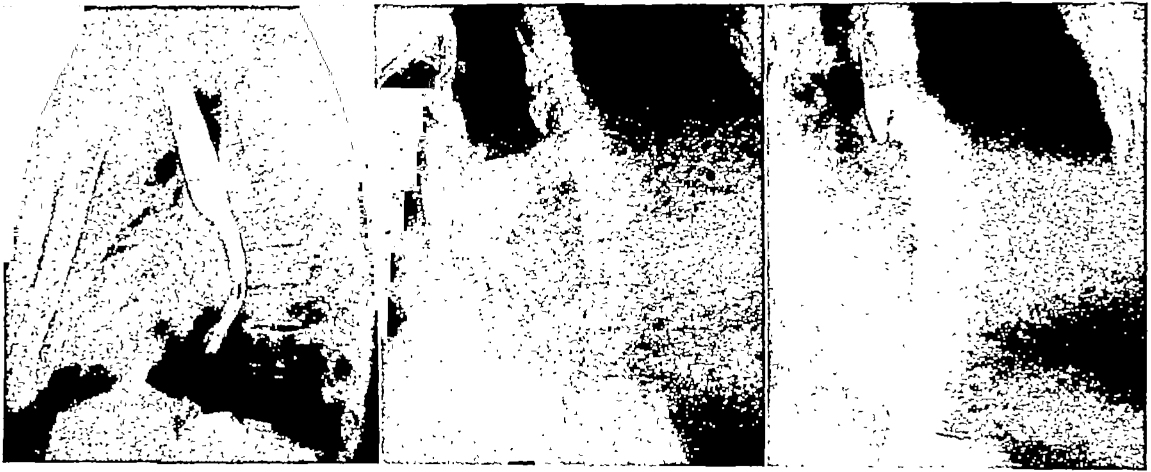


Fig. 15, *A* to *D* (Mr. J. P.).—D, Angiocardiogram on right shows obstruction to innominate vein with considerable retrograde flow into lesser radicles. *C*, Repeat gave adequate filling.

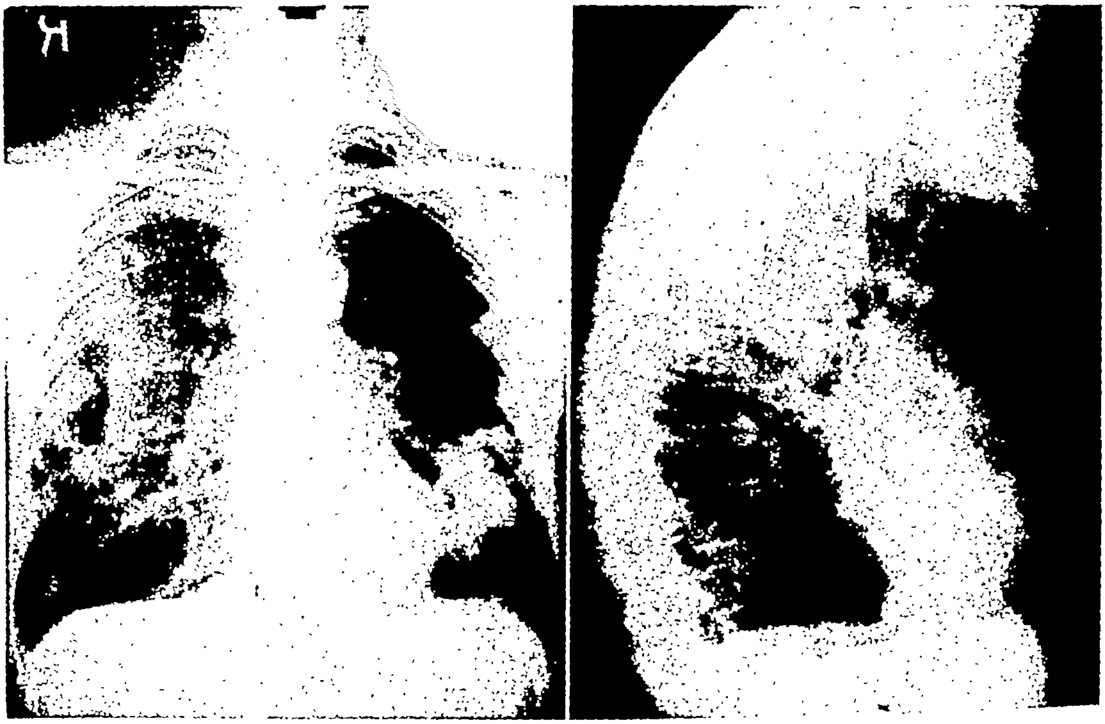


A. *B.* *C.*

Fig. 16, *A* to *C* (Mr. J. H.).—Mass anterior to esophagus displacing esophagus posteriorly. *A*, Angiocardiogram study with contrast barium to esophagus shows the lesion to be extravascular.

of the upper lobe beyond the range of the bronchoscope, and which we had not been able to visualize satisfactorily by Lipiodol studies. It is felt to be a potential valuable adjunct in the study of upper lobe tumors.

It has also been our experience recently to do exploration in a patient with carcinoma of the lingual segment associated with massive pleural effusion as his earliest symptoms. The pleural fluid was clear, and at operation the lesion was found to be entirely confined to the origin of the lingual bronchus, and the effusion secondary to infarction of the entire lingula due to malignant thrombosis. Certainly, in retrospect, angiocardiographic study might have been of considerable value in this patient. (See Fig. 17.)



A. *B.*

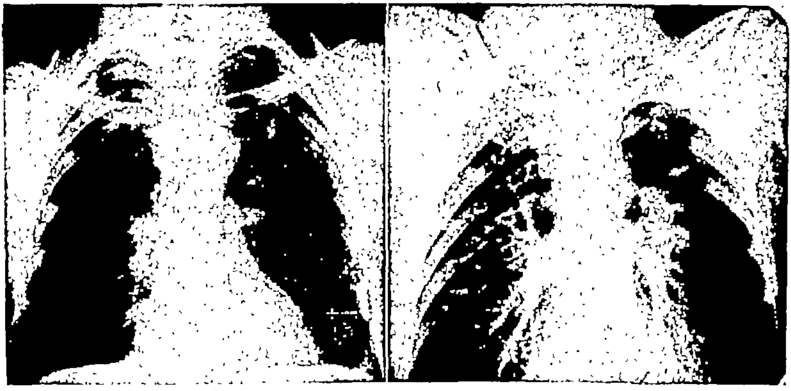
Fig. 17, *A* and B (Mr. S. B.).—Carcinoma of the lingual orifice with infarction of lingual artery. Angiocardiographic studies would have been of considerable value in this patient.

On three occasions this procedure has been carried out in the presence of nonmalignant pulmonary disease. In one case, a chronic interstitial pneumonitis of the median and dorsal basilar segments of the right lower lobe was found not to be associated with any distortion of the pulmonary vascular pattern. The second instance of suppurative disease, chronic, of the right upper lobe was found to be associated with a normal pulmonary vascular pattern. A third instance of a left paramediastinal mass due to chronic atelectasis of the left upper lobe was found to be associated with considerable distortion of the vascular pattern, but not of the obstructive type.

The use of angiocardiography in patients with advanced pulmonary emphysema to the degree which is now described as "vanishing lung disease" has not become common clinical practice because of apparent inherent dangers in this type of patient. Robb and Steinberg[12, 13] have described the pattern noted in one patient as "advanced pulmonary emphysema and fibrosis." We have carried out studies in this clinic in post-mortem specimens obtained from patients with "vanishing lung syndrome," and do feel that there is a specific pattern associated with this lesion. In the gross examination of these lungs, one is struck by the apparent disappearance of all the finer elements such as the alveoli, bronchioles, and small arteries and arterioles. Injection of the bronchi of these lungs confirms this impression, and similarly injection of the vascular tree has shown that the areas of greatest disappearance of the smaller vascular radicles is associated with the areas of major disappearance of other pulmonary structures. The application of this form of investigation in this type of patient will need to await further clinical and experimental studies.

Case histories exemplifying these statements are presented here.

CASE 1.—W. N., a 42-year-old colored man, was admitted with symptoms compatible with carcinoma of the lung. X-ray examination showed evidence of obstruction in the region of the left upper lobe. Bronchoscopic examination proved noncontributory. Lipiodol studies were repeatedly unsatisfactory for visualization of this area. Angiocardiography showed a complete obstruction of the apical segment of the left upper lobe pulmonary artery. (See Fig. 18.)

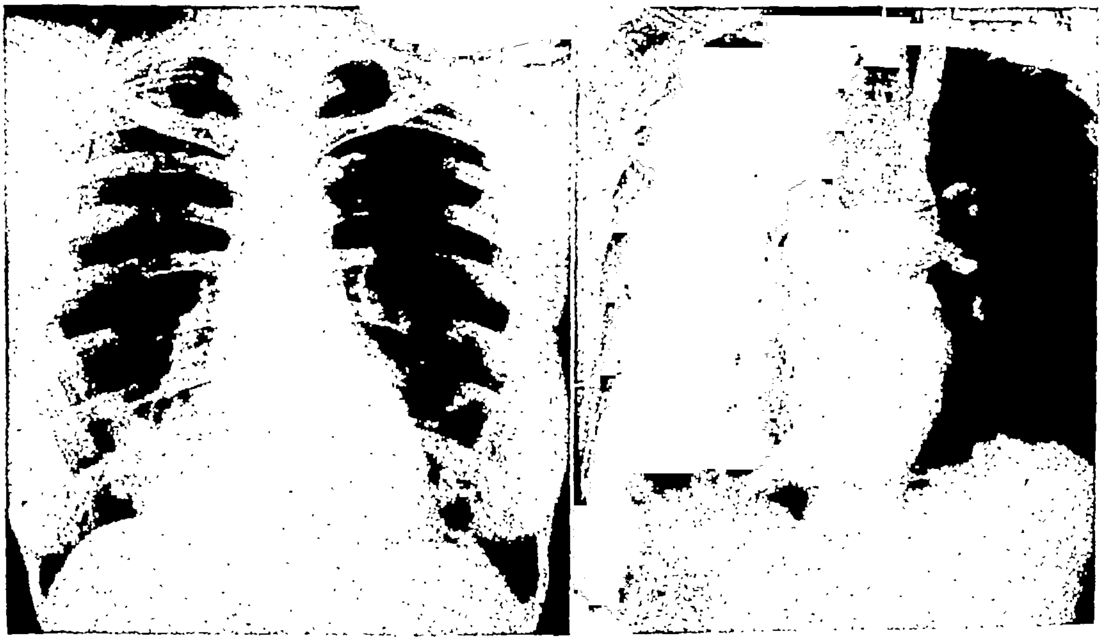


A. *B.*

Fig. 18, *A* and *B* (Mr. W. N.).—Note complete blockage of apical branch of left pulmonary artery in region of lesion.

CASE 2.—Miss L. C., a 48-year-old white woman, was admitted with the complaint of repeated severe hemorrhages with subjective localization of the point of origin to the right lower lobe. X-ray examination showed infiltration in this area with apparent partial obstruction. Bronchoscopic examination proved noncontributory. Angiocardiographic studies revealed what appeared to be a completely normal pulmonary arterial vascular pattern. At operation this lesion was resected by segmental resection, and proved to be a chronic interstitial pneumonitis. (See Fig. 19.)

CASE 3.—M. G., a 43-year-old white man, was admitted with the complaints of progressively severe dyspnea, and marked limitation of activity. He had long suffered from intractable bronchial asthma. Following intensive study the patient was operated upon. Massive pneumatoceles were removed or plicated in the right lung, and a right pulmonary plexectomy was performed. The patient progressed very well following this procedure, and five months later returned for plexectomy operation on the left lung because of persistence of bronchial asthma. The patient suffered acute ventricular fibrillation ten days following the operative procedure, and at autopsy examination the lungs showed evidence of advanced pulmonary emphysema to the degree known as "vanishing lung disease." The lungs were studied by means of Lipiodol special contrast media to visualize the bronchial and vascular tree.



A. *B.*

Fig. 19, *A* and *B* (Miss L. C.).—Mass, right lower lobe, which was proved to be a chronic interstitial pneumonitis. *B*, Angiocardiogram entirely normal.

In review of cases seen with lesions of the mediastinum and paramediastinal areas, angiocardiography has been of diagnostic value in thirteen instances. It has been of considerable aid in diagnosis and therapy in ten cases, giving a total of twenty-three cases in which definite help was obtained from this method of investigation. It was of questionable value in only seven cases, lending indirect information in these cases. This information cannot be considered of great importance until more cases have been worked up. In six cases the procedure proved of no value at all.

SUMMARY AND CONCLUSIONS

We have reviewed thirty-six patients in whom mediastinal or paramediastinal masses were studied by means of venography or angiorcardiography, or a combination of both. The series is obviously too small to derive any permanent conclusions. Certain impressions have been obtained and discussed. The subject has been discussed primarily in relation to five fundamental questions. Patients exemplifying factors involved in each of these categories have been presented. An over-all chart summarizing the findings in all forty cases is included. The following conclusions are suggested.

1. There is a definite place for the use of venography and angiocardiography in the study of mediastinal and paramediastinal masses.

2. The angiocardiogram provides the most valuable method of differentiation between vascular and avascular lesions situated in this area.

3. This method of investigation has a definite but limited use in the study of the nonvascular tumors of the mediastinum. Its primary function in this situation is to aid in a better localization of the lesion and a better outline of its borders.

4. The relative value of angiocardiography as a method of the study of these lesions varies considerably with the area of the mediastinum involved. It is of absolute necessity in the study of all lesions of the middle mediastinum. It is of almost equal importance in the study of lesions of the superior mediastinum, especially if they are located in the right paramediastinal area.

5. Certain special technical problems associated with each type of lesion have been discussed. It is vitally necessary that careful fluoroscopic examination and multiple x-ray projection studies be carried out before determining the particular positions and combinations of angiographic methods to be utilized in the individual study of a specific case.

6. It is felt that angiocardiography can be of specific value as an aid in the study of bronchiogenic carcinoma, in particular, in lesions of the upper lobes. A specific distortion of the vascular pattern is felt to occur in patients with advance pulmonary emphysema of the type known as "vanishing lung disease."

REFERENCES

1. Robb, G. P., and Steinberg, I.: A Practical Method of Visualization of the Chambers of the Heart, the Pulmonary Circulation and the Great Vessels in Man, J. Clin. Investigation 17: 507, 1938.
2. Sussman, M. L.: The Differentiation of Mediastinal Tumor and Aneurysm by Angiocardiography, Am. J. Roentgenol. 57: 584-590, 1947.
3. Williams, R. G., and Steinberg, I.: Value of Angio-cardiography in Establishing the Diagnosis of Pericarditis With Effusion, Am. J. Roentgenol. 61: 41, 1949.
4. Abbott, O. A.: Aneurysm of Superior Vena Cava, Ann. Surg. (In press.)
5. Golden, A., and Weens, H. S.: Diagnosis of Dissecting Aneurysm of Aorta by Angiocardiography, Am. Heart J. 37: 114-118, 1949.
6. O'Loughlin, B. J.: Roentgen Visualization of the Inferior Vena Cava, Am. J. Roentgenol. 58: 67, 1947.
7. Dougherty, J., and Homans, J.: Venography, A Clinical Study, Surg., Gynec. & Obst. 71: 697-702, 1940.
8. Dos Santos, R.: Phlebography of Inferior Vena Cava, Folia urol. 35: 586, 1945, Quoted by Dougherty and Homans.[7]
9. Abbott, O. A.: Modern Methods of the Diagnosis and Treatment of Mediastinal Masses, South. Surgeon 15: 101-110, 1948.
10. Weens, H. S.: Personal communication.
11. Neuhof, H., Sussman, M. L., and Nabatoff, R. A.: Angiocardiography in the Differential Diagnosis of Pulmonary Neoplasms, Surgery 25: 178, 1949.
12. Robb, G. P., and Steinberg, I.: Visualization of the Chambers of the Heart and the Thoracic Blood Vessels in Pulmonary Heart Disease, Ann. Int. Med. 13: 12-40, 1939.
13. Sussman, M. L., Steinberg, M. F., and Grishman, A.: Contrast Visualization of the Heart and Great Blood Vessels in Emphysema, Am. J. Roentgenol. 47: 368, 1942.

DISCUSSION ON "ANGIOCARDIOGRAPHY AND AORTOGRAPHY IN THE DIAGNOSIS OF CONGENITAL CARDIOVASCULAR LESIONS" BY DR. THOMAS H. BURFORD, DR. MERL J. CARSON, AND DR. WENDELL G. SCOTT* AND "THE ROLE OF ANGIOCARDIOGRAPHY AND VENOGRAPHY IN MEDIASTINAL AND PARAMEDIASTINAL LESIONS" BY DR. OSLER A. ABBOTT, DR. WILLIAM A. HOPKINS, AND DR. TED F. LEIGH

DISCUSSION

DR. G. H. HUMPHREYS, New York.—I should like to start by congratulating Dr. Burford and his group on these beautiful studies. It is not easy to get such fine demonstrations of these lesions, as anyone who has tried to work out a system knows. The group at Presbyterian Hospital, Dr. Deterling, and Dr. Ball have been working on this problem for some years, and we have succeeded in getting what we consider successful intravenous angiocardiographies in congenital lesions which, in some cases, seemed to us so satisfactory that the more elaborate retrograde injection seems unnecessary. I should like to show a few slides to demonstrate what I mean. (Slides.)

This is the ordinary type of adult coarctation and shows, as Dr. Burford brought out, the lesion here. The next shows a child in which the coarctation at this point is shown more clearly through the more rapid injection of dye. This we have found to be the most important factor, and as you see there is a sufficient segment to assure an adequate anastomosis. The next slide shows a tetralogy of Fallot taken in the anteroposterior position; the needle is large and is placed in the external jugular vein, the dye entering the heart goes out the aorta immediately, demonstrating the overriding aorta; the pulmonary arteries are well shown in the original film, and a small constricted pulmonary artery can be seen, thus demonstrating clearly that the lesion is operable.

The next slide shows a more complicated lesion. I should like to take small issue with Dr. Burford on these complicated anomalies of the great vessels. I think they show better frequently by intervenous methods. This was a cyanotic girl who, by cardiac catheterization, gave many evidences of poor pulmonary flow and so presumably was a case for operation. However, the ordinary x-ray film showed some anomaly at the aortic arch and, as we can see here, the arch bifurcates and this is in fact a double aortic arch. It is seen to split here and here; there is a double shadow, one passing downward and entering the pulmonary artery and another passing downward as the descending aorta. On the lateral view, less clear on the slide than on the film, there is quite clearly a coarctation in the right side of the aortic arch; that is, the right arch of the double arch is coarcted. In other words, this patient is demonstrated by these films to have not only an intraventricular septal defect and overriding aorta, but also a double aortic arch and a patent ductus arteriosus, as well as coarctation of the aorta. She has all four of the lesions which are operable, but it adds up to an inoperable situation since all the blood to the lung is entering through the patent ductus arteriosus. You will note the left lung has dye in it, the right has none; a few seconds later the right lung filled from collateral vessels. She has, therefore, no right pulmonary artery for anastomosis, and operation on the left side would probably be fatal since that is the lung which is supplying most oxygen.

DR. ANDRE COURNAND, New York.—After the remarkable demonstration given by Dr. Burford, I hesitate to take issue with one statement he made concerning catheterization of the heart in young children and infants. At Bellevue Hospital, in cooperation with Dr. Himmelstein and Dr. Janet Baldwin, we have catheterized infants as young as 5 months and weighing as little as 8 pounds. The technique used is somewhat different from that employed in adults. The catheter is introduced into the saphenous vein, which has to be ligated at the end of the catheterization. A special small catheter, No. 6, with a very small bend near the tip has been devised for such cases, which permits easy access to the right ventricle and the pulmonary artery without creating a big loop in the right auricle and superior vena cava.

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*See page 860 for article by Burford, Carson, and Scott.

In one case it was demonstrated today for the first time that it is possible to visualize a patent ductus arteriosus with contrast medium. This is rather important because a differential diagnosis between an aortic septal defect and a patent ductus arteriosus is impossible with the catheterization technique.

I wonder whether, as stated by Dr. Burford, it is possible to distinguish a nonfunctioning right ventricle from a single auricle associated with a single ventricle.

Dr. Burford should certainly be complimented upon the fine demonstration of the results obtained by combining the conventional venous angiocardiography with the aortagrams.

DR. ARTHUR S. W. TOUROFF, New York.—I would like to join with Dr. Humphreys and Dr. Cournand in congratulating Dr. Burford and his associates on their beautiful demonstration of the value of visualizing the great vessels in the presence of congenital cardio vascular abnormalities. At The Mount Sinai Hospital in New York, we have been most fortunate in having the services of Dr. Marcy Sussman, one of the pioneers in angiocardiography in America. We also are greatly indebted to our physicist, Dr. Serge Feitelberg, for making many improvements in the apparatus which we use. In the differential diagnosis of certain lesions, it is important to take films at a rapid rate. Accordingly, our apparatus is able to make exposures at a rate of more than two per second. (Slides.) Our apparatus consists essentially of a battery of lead-backed cassettes which are held, one in front of the other, in a magazine. As each exposure is made, the front cassette drops into a hopper, thereby immediately leaving an unexposed cassette ready for the next exposure. The magazine holds fifteen cassettes which can be exposed in seven seconds if desired. An important component of our apparatus is the ''amplifier-synchronizer.'' This permits us to synchronize the taking of films with the electrocardiograph. Through the medium of a series of twenty-two switches, which may be pre-set as desired, exposures also can be made automatically at any desired interval. Thus, the apparatus can be operated manually, or the switches may *be set to take films at predetermined intervals, or finally the apparatus may* be controlled by the electrocardiograph to take films in any desired phase of the cardiac cycle. The latter at times is important because, under certain circumstances, great errors in interpretation may be made. I would like to demonstrate how such an error may occur. (Slide.) Here is a film taken four one-hundredths second after the peak of the R wave. You see the dye coming down the superior vena cava to enter the right atrium. The exposure has been made at the beginning of systole of the right ventricle. The pulmonic valve and pulmonary artery are outlined, and the ventricle is filled with dye. (Slide.)

This second film is taken twenty-five one-hundredths second after the peak of the R wave. This is the end of systole of the right ventricle. You will note that, in this view, the right ventricle is practically empty. However, the pulmonary artery is filled with dye. If, by accident, one happened to make the exposure at this particular time without knowing what came before, one might be led to the conclusion that the patient was suffering from pulmonic stenosis. Incidentally, this film illustrates the fact that the left pulmonary artery normally rises to a higher level than the right. (Slide.)

This third film is taken precisely two heartbeats after the filling of the right atrium. The dye fills the right auricle, the right ventricle, the pulmonary artery, the left auricle, the left ventricle, and the aorta. Accordingly, the diagnosis of a septal defect is obvious. The common carotid with its branches, the external and internal carotid, are well visualized. At this point, the right subclavian is seen, and here are the left carotid and left subclavian arteries.

Our x-ray department has done more than 2,000 angiocardiograms without a death. We attribute this to the fact that every patient is tested very carefully for sensitivity to iodine. A test dose of 1 c.c. intravenously is given to every adult; every child receives 0.5 c.c. intravenously. An untoward reaction to these test doses eliminates the patient from further study by means of angiocardiography. Practically every patient has some reaction during angiocardiography, although these reactions usually are mild. Weakness, pallor, sweating, and a feeling of warmth are common. However, we have never had a death, nor have we observed any serious complications following the procedure.

Those who are interested will find a description of the apparatus which we employ in a forthcoming publication.*

DR. OSLER ABBOTT, Atlanta, Ga.—I wish to bring to your attention the role of the ballistocardiogram in the study of certain congenital heart lesions. (Slides.) This is the instrument which is used, and its fundamental use, of course, is determination of cardiac index and cardiac output. The thing that is interesting is the changes that occur in coarctation, and that there is a specific wave with this machine in two diseases, coarctation of the aorta and primary thrombosis of the aorta. The fundamental change is seen in the K wave. The K wave in coarctation of the aorta preoperatively, shows the notching of the descending limb in that wave. The I wave is also of interest, and is mainly an indication of an overactive heart, and is increased in certain lesions. The postoperative tracing on a patient in whom a direct aortic end-to-end anastomosis was possible, and in whom there was a large distal aorta, showed essentially complete conversion of the K wave to normal.

In another patient the K wave was even more distorted with a low fall and very jagged descent, and there was a very marked increase in the I wave in the descending limb. This patient was operated upon in the early group by an end-to-side shunt, using the subclavian artery to the aortic wall, and it showed in the postoperative period that the conversion of the K wave was in no way comparable to the satisfactory conversion in the preceding patient.

Here is the tracing made on another patient with the preoperative K wave markedly flattened, and in the postoperative period the flattening was corrected, particularly in the height of the limb of the K wave, better than the preceding one; the notching persisted because of severe hypoplasia of the entire descending thoracic aorta, noted at the time of end-to-end aortic anastomosis.

The same thing can be seen in another patient in whom there was a marked degree of aortic insufficiency, showing the marked enlargement of the I wave in the preoperative stage, and this shows the postoperative change in the K wave which we feel is satisfactory, though a little limited because of the fact that the aorta was rather smaller than normal, but the I wave is not changed because the insufficiency, of course, has not been radically corrected.

We feel this is an additional method not only of making diagnosis of coarctation of the aorta but also evaluating postoperative results in different types of methods used.

DR. H. BRODIE STEPHENS, San Francisco.—I think a word of caution should be given at this time; perhaps Dr. Burford has it in his original manuscript. It is very important to remember in retrograde carotid arteriograms to block off completely the distal carotid, particularly when a 70 per cent Diodrast solution is being utilized. Neurosurgeons, of course, have given up this solution in their visualization of the cerebral vessels. Only recently, in one of our cases, unfortunately the distal carotid was not obliterated, and the patient developed hemiplegia on the right side when we used the left common carotid. Fortunately, he recovered by stellate ganglion block on three different occasions. But this is a very definite danger in retrograde arteriograms, and we now have adopted the technique of always completely obliterating the distal carotid by the use of a bulldog clamp.

DR. E. E. AVERY, Chicago.—Dr. Burford and his associates are to be complimented for developing their excellent techniques and mechanical devices to improve this procedure. At Hines Hospital, we have carried out this dye visualization in well over fifty cases involving the differential diagnosis of mediastinal and paramediastinal masses. I would like to emphasize that this can be a relatively easy procedure which can be carried out in any hospital without expensive equipment. We use a Robb-Steinberg syringe and needle and a standard stereocassette changer to take our roentgenograms. It takes only a little practice and patience in developing the proper technique of circulation times and in taking exposures at the right intervals. Certainly in infants with cardiovascular anomalies, it is necessary to have rapid multiple exposures to obtain the desired information. However, in adults with mediastinal lesions, the diagnostician should be encouraged to try this procedure with the simple equipment mentioned, because it will yield a great deal of valuable information.

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*Medical Physics, ed. 2, edited by Dr. Otto Glaser, Chicago, 1949, The Year Book Publishers, Inc.

Where there is vascular obstruction of the mediastinum, as is illustrated in this slide, we have found the angiocardiogram of value to the surgeon. Here can be seen a massive obstruction; the subclavian is blocked, and the dye has to come in through the supreme intercostals into the azygos system. This is of value in three ways: it allows the surgeon to know better just what problems he will encounter; by knowing the major collaterals, damage to them can be avoided during exploration of the chest; if the case is inoperable, it helps the x-ray therapist to direct the roentgen bombardment to the area at which the tumor mass has occluded the vessels—in other words, he has a better idea as to the location of tumor tissue in the mediastinal shadow.

Every surgeon has at one time or another found an aneurysm at exploratory thoracotomy where he fully expected to find tumor, and vice versa. Therefore, angiocardiography should be done in mediastinal lesions because: (1) It aids in planning the approach and the procedure to be used; (2) it allows the surgeon to avoid unnecessary exploration; (3) it confirms and justifies necessary thoracotomies.

I want to re-emphasize that this valuable information can be gained in appropriate cases with a little experience and with relatively simple apparatus available in any hospital. Watchful waiting in these lesions is dangerous, and the danger of the procedure itself is by far outweighed by the valuable information which can be obtained.

DR. J. A. HELMSWORTH, Cincinnati.—The approach to a small portion of the problems covered so well by Dr. Abbott has been a method of arteriography by countercurrent catheterization of the aorta. The contrast medium, Diodrast, is injected in small volumes rapidly and with the usual simple x-ray apparatus single films are taken. (Slides.)

This shows the catheter that has been improvised. It is made of Polyethylene tubing with an outer diameter of .098 and an inner diameter of .068 and with a 15 gauge needle used as an adapter. This is a posteroanterior view of the chest of a patient with syphilis and under suspicion for aneurysm of the innominate artery. With the catheter inserted through the brachial artery at the level of the distal end of the humerus, the tip was advanced to the origin of the innominate artery and with the injection of approximately 10 c.c. of Diodrast some visualization of the small remaining lumen was obtained. The thickness of the wall of the aneurysm was outlined, as well as the vertebral artery.

This patient also had syphilis. In the posteroanterior view the location of a mass suspected of being aneurysm was outlined. With the introduction of the catheter through the brachial artery on the right, advancing the tip down into the origin of the aorta, and the injection of a small amount of Diodrast, approximately 12 c.c., it outlined the general course of the arch of the aorta and indicated in a rather vague way the outline of the related aneurysm.

This patient also was suspected of having an aneurysm of the innominate artery, and the posteroanterior view gives the reason for this. Some difficulty was encountered in advancing the catheter beyond the brachial artery and finally, when it could not be brought into the innominate or down into the origin at the aorta, 8 c.c. of Diodrast were injected, and a definite outline of an occluding process of the subclavian is shown. This is concluded to be the wall of the aneurysm in relation to the subclavian artery and occluding the same by extrinsic pressure.

This outlines in much less contrast than Dr. Burford's cases the approximate limits of the aorta, the subclavian artery, the coarcted portion of the aorta, and the distal portion of the aorta. Here can be seen the left internal mammary artery and a little further in the same direction is the right internal mammary. This vessel is the left subclavian artery with a take-off quite near the origin of the upper limit of the coarctation.

This Negro, having been shot through the right side of the neck, was thought to have an arteriovenous communication at the level of the hyoid bone; here is the catheter through the brachial artery. The Diodrast demonstrates very well the vertebral artery and the ascending cervical artery. This shows filling of the common carotid, the aneurysmal sac, and incomplete filling of the venous channels involved in the same process.

DR. HAROLD NEUHOF, New York.—I believe we are all equally appreciative of Dr. Abbott's presentation of this subject, the first presentation, I think, which has been made before this Society, of an extremely useful method of diagnosis in a great variety of intrathoracic conditions. His study, as you have seen, is truly encyclopedic, and you can also see the innumerable possibilities which are opened up for us all in further development of this work.

He has referred to some of our own work, and that has been particularly concerned with, first, the effort to demonstrate the influence of intrathoracic lesions which are mediastinal on the pattern of superior vena cava and innominate veins and pulmonary artery, and not in so far as intracardiac patterns are concerned; and second, the effect on the pattern of the pulmonary artery of lesions within the lung. It would go too far afield to refer to our various experiences which have, in a general way, been along the lines to which Dr. Abbott has referred this afternoon. In a recent publication in *Surgery* we reviewed our experiences. In so far as visualization in connection with mediastinal lesions is concerned, I would say that, according to our experience, a negative angiogram, that is, a normal pattern of the branches of the pulmonary artery, is often as interesting and significant as a positive one. I hope Dr. Touroff will show the films of a patient who had an enormous shadow chiefly in the anterior mediastinum, which, however, did not indent at all the pattern of the contrasted visualization of the heart and great vessels. The lesion at operation proved to be a thymoma of soft consistency. Most surgical mediastinal lesions are not related to the great vessels, and therefore, according to our experience, the contrast visualization of the great vessels has been one of a negative nature. Indeed a positive film, that is a distortion or block of one of the great vessels points to a surgically irremediable lesion in my experience.

Concerning pulmonary lesions, which I should like to discuss specifically, Dr. Abbott has pointed out the block of a branch of a pulmonary artery in some cases, which has confirmed for him, and I think entirely properly so, the diagnosis of cancer of the lung. We are of the opinion, according to our experiences which have been reported, that an angiogram or rather a pulmonary arteriograph which demonstrates a block of either the main trunk or a major branch is truly a pathognomonic sign of cancer of the lung. That is, of course, a dangerous thing to say, but it has been so in our experience up to the present. The important point is that this does not at all establish that such a lesion is inoperable. Steinberg, a master in the field of pulmonary angiography, some months ago referred to a number of cases in which he noted this blockade, and it was his opinion and his experience that these blocks accompany an inoperable condition. However, in a discussion of the matter, he agreed that it was perhaps the type of material with which he came in contact which lead to this view. We have seen upon a number of occasions the diagnosis definitely established of cancer of the lung, which could not otherwise have been established by angiograms. Since we all agree that we are no longer in the stage when we say let us explore and find out the nature of the lesion, if we can diagnose the lesion prior to operation I think we should bear in mind not only the possibility but the probability of specific aid in diagnosis by this method which, I should like to emphasize as Dr. Abbott has already done, is entirely free from danger when performed under proper auspices.

DR. ROLLINS HANLON, Baltimore.—I should like to emphasize the word of caution which Dr. Burford expressed in his excellent presentation. We have not been as fortunate as Dr. Sussman and his collaborators in their tremendous experience of some 2,000 cases. The experience of our radiologic and surgical departments comprises more than 600 injections in over 300 patients with congenital cardiovascular disease, predominantly of the cyanotic type. While these are admittedly substandard risk patients, the fact that there have been three deaths in our series leads us to feel that the procedure should not be used indiscriminately and without serious consideration as to the benefits to be obtained by this method of examination. All of our patients received an intravenous test dose of iodopyracet; it is obvious that a negative reaction to such a test does not rule out the possibility of a fatal outcome. One should not use iodopyracet injection unless he feels that the diagnostic requirements warrant the not inconsiderable danger in these substandard risk patients.

I should like to show several slides illustrating a modification of our standard technique as recently employed in cases of coarctation of the aorta. In conjunction with Dr. Cooley and Dr. Sloan of our radiology department, Dr. Harry Muller has incised the radial artery below the elbow and passed a catheter to the vicinity of the aortic coarctation. This permits better visualization of the vessels about the coarctation, while employing considerably smaller amounts of iodopyracet than is usually given by the intravenous method. The first slide shows an excellent view of an aortic coarctation after injection of 50 c.c. of iodopyracet through an antecubital vein. The clarity of detail is much better than we usually obtain by this technique. In contrast, the next slide represents the film obtained after injection of only 20 c.c. of the dye through a catheter with its tip lying near the coarctation; the detailed anatomy of the region is seen much more clearly. In the next slide can be seen a demonstration of patent ductus arteriosus in conjunction with coarctation, and in the final slide there is demonstrated an aneurysm of the intercostal artery just below a coarctation. In this latter instance the additional surgical procedure and the increased risk incident to aortic catheterization seemed justified by the additional information which was of great value to the surgeon.

Angiocardiography has been used in all but a few of the forty-six patients with coarctation of the aorta operated upon by Dr. Blalock and his associates. Recently, injection through an inlying aortic catheter has replaced simple intravenous injection in patients suspected of coarctation. It is to be emphasized, however, that intravenous injection is still used as the customary technique in most other instances, especially in the poor-risk, cyanotic patient.

DR. CARSON.—Being a pediatrician I rather feel that I should apologize for appearing before this meeting. It is a great privilege, however, and my only excuse is that I am a part of a team, with the thoracic surgeons, in trying to work out these congenital malformations of the heart. There are a number of points I would like to emphasize in detail. The first refers to Dr. Cournand's question about the differentiation of the nonfunctioning right ventricle, as shown by angiocardiography, as differentiated from the picture of a single great auricle and a single ventricle. Again I must apologize for omitting the first slide in the series Dr. Burford showed. This was omitted for the sake of brevity. However, *on the first picture obtained on that patient, taken about two-thirds second before*, one could see very definite filling of the right auricle, with no Diodrast being seen in the ventricle. There was a very small amount of Diodrast in the left auricle at that time. In the following plate, as you saw, could be noticed the right auricle, the left auricle, and the left ventricle, with no right ventricle being visualized.

Again I wish to emphasize that this is another laboratory procedure. One should not attempt to make it the only laboratory procedure or method of examination used. We use it in conjunction with the other studies, and these other studies would also help reveal the difference between the two conditions.

I would like to comment on Dr. Touroff's question regarding test doses of Diodrast. We feel this is extremely important. We abandoned the intradermal testing for sensitivity to Diodrast because we obtained so many false positive reactions. In every patient on whom we do angiograms or arteriograms we inject intravenously, as Dr. Touroff does, a small amount of Diodrast before the procedure is undertaken. We also make sure of good renal function by doing a nonprotein nitrogen test before the angiogram is done.

Dr. Stephens brought up the question of obliteration of the left common carotid artery cephalad to the point of injection. That is always done; the cannula is inserted into the left common carotid artery and a ligature is tied around the cannula so there is no possibility for the Diodrast to go directly up into the brain.

I certainly would agree wholeheartedly with Dr. Hanlon's position as just stated and, in contrast to Dr. Avery's remarks, I really do not feel that this is a procedure to be undertaken lightly. We have seen a number of reactions, particularly in the very cyanotic group of children who are in poor condition at the beginning. We feel that if other measures will give a definite diagnosis, this method of examination should be avoided. We do not feel it is an easy procedure and feel that it has very definite dangers. When it is definitely indicated, however, we feel that one should not hesitate to use it.

In conclusion, there is one further point I would like to make. In our group we feel there is a very definite challenge to the thoracic surgeons and to the pediatricians, in children, during the first few weeks or months of age, who have the infantile type of coarctation of the aorta. These are the children who present themselves with the picture of cardiac failure and not the typical picture of the adult type of coarctation of the aorta. In our experience during the last two years we have had nine such patients in St. Louis Children's Hospital, and they have uniformly died within a period of one day to three or four weeks after admission. We feel this is a definite group of patients who could and should be benefited if they can be brought out of cardiac failure long enough for remedial surgery to be performed.

DR. HOPKINS.—As has been pointed out, we too feel that these patients should be chosen carefully, not only with regard to those who will benefit by the procedure but also with regard to the selection of the patients. The radiology department has done more than 700 injections at this time without a death. They have steadfastly refused to do an injection in any patient with severe coronary disease or any patient with evidence of severe bronchospasm, and also those with an extreme degree of renal disease.

We also feel that in the use of the venogram a less amount of dye may be injected, and 35 per cent dye may be used in these patients. I would like also to say that there is one other lesion in which we feel that this procedure may be of extreme benefit in diagnosis, that is, arteriovenous aneurysm of the lung, but to this date we have not had any experience in this category.

ANNOUNCEMENT

It is a pleasure to announce that arrangements have been completed which will make possible the conversion of the JOURNAL from a bimonthly publication to one which will appear monthly. This change will begin with the first number of Volume 19, January, 1950. The C. V. Mosby Company has generously granted to The American Association for Thoracic Surgery not only the privilege of having regularly in its official journal 108 pages in each monthly issue but also the opportunity to publish during the year 1950 approximately 50 more pages in each issue in order to clear up a large number of accumulated papers which have been held for long periods because of the previous restricted number of pages. It is expected, therefore, that from now on it will be possible to print accepted articles much more promptly than previously.

In order to make the change to a monthly publication it will be necessary to increase the subscription price in the United States from $10 to $15 per year. The Council of the Association has authorized this increase.

The enormous interest in thoracic surgery which now exists throughout the world and the great speed with which it is being developed amply justify the change in policy of the JOURNAL. I feel certain that those who are interested in this field of surgery will welcome it.

—*The Editor*

The American Association for Thoracic Surgery

1949-1950

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NOTICE

The thirtieth annual meeting of the American Association for Thoracic Surgery will be held April 15, 16, 17, and 18, 1950, in Denver, Colo. Headquarters will be at the Cosmopolitan Hotel.

Requests for hotel reservations should be mailed direct to Col. James H. Forsee, 519 17th Street, Denver, Colo.

Abstracts for presentation of papers for the 1950 meeting must be received for consideration by the Program Committee on or before Jan. 1, 1950. These abstracts should be submitted in *quadruplicate* and addressed to the Secretary of the Association, Dr. Brian Blades, George Washington University Hospital, 901 23rd Street, N. W., Washington 7, D. C. They should not be sent to the Editor. Abstracts received after Jan. 1, 1950, will not be considered.

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